IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
SHERMAN DIVISION

FAR NORTH PATENTS, LLC, Plaintiff, v. TEXAS INSTRUMENTS, INC., Defendant.	CIVIL ACTION NO. 4:19-cv-946 ORIGINAL COMPLAINT FOR PATENT INFRINGEMENT **JURY TRIAL DEMANDED**

ORIGINAL COMPLAINT FOR PATENT INFRINGEMENT

Plaintiff Far North Patents, LLC ("Far North Patents" or "Plaintiff") files this original complaint against Defendant Texas Instruments, Inc. ("TI" or "Defendant"), alleging, based on its own knowledge as to itself and its own actions and based on information and belief as to all other matters, as follows:

PARTIES

1. Far North Patents is a limited liability company formed under the laws of the State of Texas, with its principal place of business at 18383 Preston Rd Suite 250, Dallas, Texas, 75252.

2. Defendant Texas Instruments, Inc. is a corporation organized and existing under the laws of Delaware. Texas Instruments, Inc. may be served through its registered agent, CT Corporation System, at 1999 Bryan Street, Suite 900, Dallas, TX 75201.

JURISDICTION AND VENUE

3. This is an action for infringement of United States patents arising under 35 U.S.C. §§ 271, 281, and 284–85, among others. This Court has subject matter jurisdiction of the action under 28 U.S.C. § 1331 and § 1338(a).

4. This Court has personal jurisdiction over TI pursuant to due process and/or the Texas Long Arm Statute because, *inter alia*, (i) TI has done and continues to do business in Texas; (ii) TI has committed and continues to commit acts of patent infringement in the State of Texas, including making, using, offering to sell, and/or selling accused products in Texas, and/or importing accused products into Texas, including by Internet sales and sales via retail and wholesale stores, inducing others to commit acts of patent infringement in Texas, and/or committing a least a portion of any other infringements alleged herein, and (iii) TI is registered to do business in Texas.

5. Venue is proper in this district as to TI pursuant to 28 U.S.C. § 1400(b). Venue is further proper because TI has committed and continues to commit acts of patent infringement in this district, including making, using, offering to sell, and/or selling accused products in this district, and/or importing accused products into this district, including by Internet sales and sales via retail and wholesale stores, inducing others to commit acts of patent infringement in this district, and/or committing at least a portion of any other infringements alleged herein in this district. TI also has a regular and established place of business in this district, including at 6412 US-75, Sherman, TX 75090 (as shown in the below screenshot from Google Maps Street View).

BACKGROUND

6. The patents-in-suit generally pertain to communications networks and other technology used in the provision of wireless services, Voice over Internet Protocol ("VoIP") phone systems, high speed networking, and other advanced communication services. The technology disclosed by the patents was developed by personnel at MCI WorldCom ("WorldCom") and Path1 Network Technologies Inc. ("Path1 Network Technologies").

7. WorldCom was a leading telecommunications service provider in the late 1990s and early 2000s. Verizon acquired WorldCom in 2005. The patents developed at WorldCom ("the Hardy patents") are related to Quality of Service ("QoS") evaluation in telecommunications systems.

8. The inventor of the Hardy patents, former principal analyst for quality measurement and analyses at WorldCom Dr. William C. Hardy, was at the forefront of QoS in telecommunications systems. Dr. Hardy developed, disclosed, and patented a solution for

efficiently and consistently evaluating QoS. In fact, Dr. Hardy literally wrote the book on QoS in telecommunications systems. *See* Hardy, William C., QoS Measurement and Evaluation of Telecommunications Quality of Service (Wiley 2001).

9. Dr. Hardy has received considerable praise for his work in QoS. Luis Sousa Cardoso, Quality of Service Development Group Chairman, left little doubt regarding the esteem with which he holds Dr. Hardy: "William C. 'Chris' Hardy is unquestionably among the leading lights in the field of QoS[.]" Dr. Hardy's book was reviewed in *IEEE Communications Magazine*, Vol. 40, No. 2, Feb. 2002, which stated that the book "provides a straightforward and very accessible approach to measurement and evaluation of QoS in telecommunications networks…strongly recommended for all people, either experiences professionals or graduates, involved in the area of networking[.]" He is even an honorary member of the Russian Academy of Science.

10. The Hardy patents (or the applications leading to them) have been cited during patent prosecution hundreds of times, by numerous leading companies in the computer networking and telecommunications industries industry, including Adtran, Alcatel-Lucent, Arris, AT&T, Avaya, Cisco, Deutsche Telekom (T-Mobile), Dolby Laboratories Licensing Corporation, Empirix, Ericsson, Genband, General Electric, IBM, Juniper, Microsoft, Motorola, NEC, Oracle, Panasonic, Ringcentral, Sharp, Siemens, Sprint, USAA, and Verizon.

11. Path1 Network Technologies is a provider of video over IP services and solutions. The patents developed at Path1 Network Technologies ("the Fellman patents") relate to providing service guarantees for time sensitive signals in computer networks. The inventors of these patents include Dr. Ronald D. Fellman and Dr. Rene L. Cruz. Drs. Fellman and Cruz, both former professors of electrical and computer engineering at the University of California at San

Diego, were pioneers in network technology. Dr. Fellman was an IEEE Senior Member, and his work was published in several IEEE Transactions journals, including IEEE Transactions on Networking, IEEE Transactions on Parallel and Distributed Systems, IEEE Transactions on Systems, Man, and Cybernetics, IEEE Transactions on Signal Processing, IEEE Transactions on Very Large Scale Integration (VLSI) Systems, IEEE Transactions on Acoustics, Speech and Signal Processing. He was also a co-founder of Path1 Network Technologies and of Qvidium Technologies. Dr. Cruz, a distinguished scholar in the field of communication networks, was said to have established the field of Network Calculus. In Dr. Cruz's election to be a Fellow of the IEEE in 2003, he was "cited for his expertise in the area of Quality-of-Service guarantees in packet-switched networks." http://jacobsschool.ucsd.edu/news/news_releases/release.sfe?id=1385.

12. The Fellman patents (or the applications leading to them) have been cited during patent prosecution hundreds of times, by numerous leading companies in the computer networking and telecommunications industries, including ABB Research, AMD, Amazon, AT&T, Atheros Communications, Avaya, Bose, Broadcom, Canon, Centurylink, Chi Mei Optoelectronics, Ciena, Cox Communications, Dell, F5 Networks, Fujitsu, Hitachi, Honeywell, Intel, IBM, Lucent, Lutron, Microsoft, National Instruments, National Semiconductor, NEC, Nortel Networks, Oceaneering, Phillips, Qualcomm, Robert Bosch, Samsung, Siemens, Sonos, Sony, Symantec, Texas Instruments, Toshiba, Ubiquiti Networks, Verizon, and Viasat.

COUNT I

DIRECT INFRINGEMENT OF U.S. PATENT NO. 8,689,105

13. On April 1, 2014, United States Patent No. 8,689,105 ("the '105 Patent") was duly and legally issued by the United States Patent and Trademark Office for an invention entitled "Real-Time Monitoring of Perceived Quality of Packet Voice Transmission."

14. Far North Patents is the owner of the '105 Patent, with all substantive rights in and to that patent, including the sole and exclusive right to prosecute this action and enforce the '105 Patent against infringers, and to collect damages for all relevant times.

15. TI made, had made, used, imported, provided, supplied, distributed, sold, and/or offered for sale products and/or systems including, for example, its TI Telogy Software and TI TNETV3020 Carrier Infrastructure Platform families of products that include advanced quality monitoring capabilities (collectively, "accused products").

Telogy Software™ products for VoIP

TI's Telogy Software products provide the broadest range of VoIP features available. As new TI device architectures evolve, so too do Telogy Software features to take advantage of new system interfaces and performance.

Key software capabilities include:

- Voice processing for PSTN to packet gateway applications
- T.38 fax relay
- Conference bridge
- Signaling
- Voice and call quality management

With the largest installed base of field-hardened gateway-specific solutions since 1995, Telogy Software provides world-class VoIP software solutions that industry giants rely on. Every level of VoIP product benefits from the breadth of the software deployments and improvements.

Voice and call quality management

Fundamental to any communications system is the ability to discover, isolate and remedy problems as quickly as possible to minimize or eliminate the degree to which users are impacted. VoIP networks must support telco-grade management and diagnostics for wide-scale, cost-effective deployments.

TI's voice and call quality management features include:

- Real-time measures such as mean opinion score (MOS) estimation based on delay, jitter and packet loss statistics
- Support for RFC3611 Real-Time Protocol Extended Reports (RTCP XR)
- Detailed call statistics for fax, tone detection, echo, error stats and packet stats
- Diagnostic tools for detailed troubleshooting: trace, fax, echo, TDM or packet interfaces, analog line tests
- Alerts/alarms with configurable thresholds
- Optimized adaptive jitter buffer, packet loss concealment and redundancy

(Source : www.ti.com/lit/ml/spat180a/spat180a.pdf)

TNETV3020

Carrier Infrastructure Platform

Telogy Software™ products integrated with TI's DSP-based high-density communications processor

TEXAS INSTRUMENTS

(Source : http://www.ti.com/lit/ml/spat174a/spat174a.pdf)

PIQUA™ technology

The TNETV3020 software includes support for TI's award-winning quality-initiative PIQUA technology. PIQUA technology provides easy access to comprehensive network diagnostics and statistics in a standards-based architecture. This support vastly improves the carrier's ability to find and fix problems within the network and enhance the user's experience. PIQUA technology provides added value for carriers through statistics such as the following:

- Echo Quality Index (EQI) – provides a measure of the propensity for echo on any given conversation
- Packet loss recovery statistics – measures the effectiveness of packet loss recovery mechanisms
- Fax and modem performance indicators
- Customized quality alerts
- Support for RTCP-XR (RFC 3611)
- RTCP-HR

(Source : http://www.ti.com/lit/ml/spat174a/spat174a.pdf)

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RFC 3611                        RTCP XR                    November 2003

References

Normative References

   [1]  Bradner, S., "Key words for use in RFCs to Indicate Requirement
        Levels", BCP 14, RFC 2119, March 1997.

   [2]  Crocker, D., Ed. and P. Overell, "Augmented BNF for Syntax
        Specifications: ABNF", RFC 2234, November 1997.

   [3]  ETSI, "Quality of Service (QoS) measurement methodologies", ETSI
        TS 101 329-5 V1.1.1 (2000-11), November 2000.

   [4]  Handley, M. and V. Jacobson, "SDP: Session Description
        Protocol", RFC 2327, April 1998.

   [5]  Hovey, R. and S. Bradner, "The Organizations Involved in the
        IETF Standards Process", BCP 11, RFC 2028, October 1996.

   [6]  ITU-T, "The E-Model, a computational model for use in
        transmission planning", Recommendation G.107, January 2003.

   [7]  Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA
        Considerations Section in RFCs", BCP 26, RFC 2434, October 1998.
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(Source : https://tools.ietf.org/html/rfc3611)

```
  MOS-CQ: 8 bits
        The estimated mean opinion score for conversational quality
        (MOS-CQ) is defined as including the effects of delay and other
        effects that would affect conversational quality.  The metric
        may be calculated by converting an R factor determined
        according to ITU-T G.107 [6] or ETSI TS 101 329-5 [3] into an
        estimated MOS using the equation specified in G.107.  It is
        expressed as an integer in the range 10 to 50, corresponding to
        MOS x 10, as for MOS-LQ.

        A value of 127 indicates that this parameter is unavailable.
        Values other than 127 and the valid range defined above MUST
        not be sent and MUST be ignored by the receiving system.
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(Source : https://tools.ietf.org/html/rfc3611)

16. By doing so, TI has directly infringed (literally and/or under the doctrine of equivalents) at least Claims 1 and 23 of the '105 Patent. TI's infringement in this regard is ongoing.

17. TI has infringed the '105 Patent by using the accused products and thereby practicing a method that includes obtaining, by a network device, a reference matrix based on

estimates of perceived audio quality of at least portions of one or more first packetized audio messages, the reference matrix modeling values of a plurality of characteristics associated with a particular quality level. For example, the accused products are used by TI to implement the ITU-T G.107 Recommendation. The quality of audio in VoIP networks (packet switched networks) are calculated using MOS (Mean Opinion score) values according to ITU-T G.107 Recommendation E-model. The E-model computes a transmission rating value R, which is a combinational effect of all the transmission parameters in an audio conversation. The E-model uses a reference table ("reference matrix") based on the estimates of perceived audio conversational/audio quality. The reference table includes modelling values like MOS-CQE (Mean Opinion Score – Estimated Conversational Quality), each associated with a quality level.

7 Target services

This Recommendation gives guidelines for QoE assessment of various telecommunication services mainly utilizing audio and visual media.

7.1 Audio

– Conversational voice and voice messaging

Speech communication services such as mobile telephony and voice over Internet protocol (VoIP), as well as conventional public switched telephone network (PSTN) and integrated services digital network (ISDN) services, are important targets of this Recommendation. The speech bandwidth can be either narrowband (NB) (300-3400 Hz) or wideband (WB) (100-7000 Hz).

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-G.1011-201506-S!!PDF-E&type=items)

8.5 Planning models

The input for planning models (Figure 8-5) includes the quality planning parameters of networks or terminals. It usually requires prior knowledge about the system under test. Such models can be applied to network planning and terminal/application design.

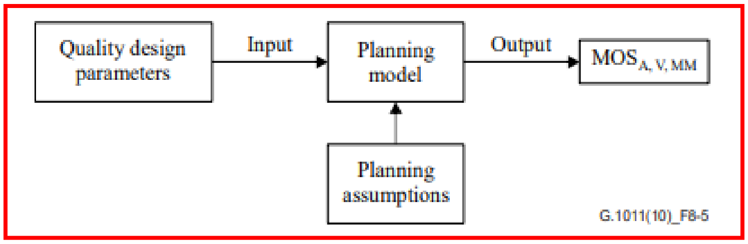


Figure 8-5 – Planning model

Standard examples of such models are [ITU-T G.107] for speech and [ITU-T G.1070] for videophone.

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-G.1011-201506-S!!PDF-E&type=items)

Recommendation ITU-T G.107

The E-model: a computational model for use in transmission planning

1 Scope

This Recommendation describes a computational model, known as the E-model, that has proven useful as a transmission planning tool for assessing the combined effects of variations in several transmission parameters that affect conversational[1] quality of 3.1 kHz handset telephony. This computational model can be used, for example, by transmission planners to help ensure that users will be satisfied with end-to-end transmission performance whilst avoiding over-engineering of networks. It must be emphasized that the primary output from the model is the "rating factor" *R* but this can be transformed to give estimates of customer opinion. Such estimates are only made for transmission planning purposes and not for actual customer opinion prediction (for which there is no agreed-upon model recommended by the ITU-T).

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

7 Structure and basic algorithms of the E-model

The E-model is based on the equipment impairment factor method, following previous transmission rating models. It was developed by an ETSI ad hoc group called "Voice Transmission Quality from Mouth to Ear".

The reference connection, as shown in Figure 1, is split into a send side and a receive side. The model estimates the conversational quality from mouth to ear as perceived by the user at the receive side, both as listener and talker.

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

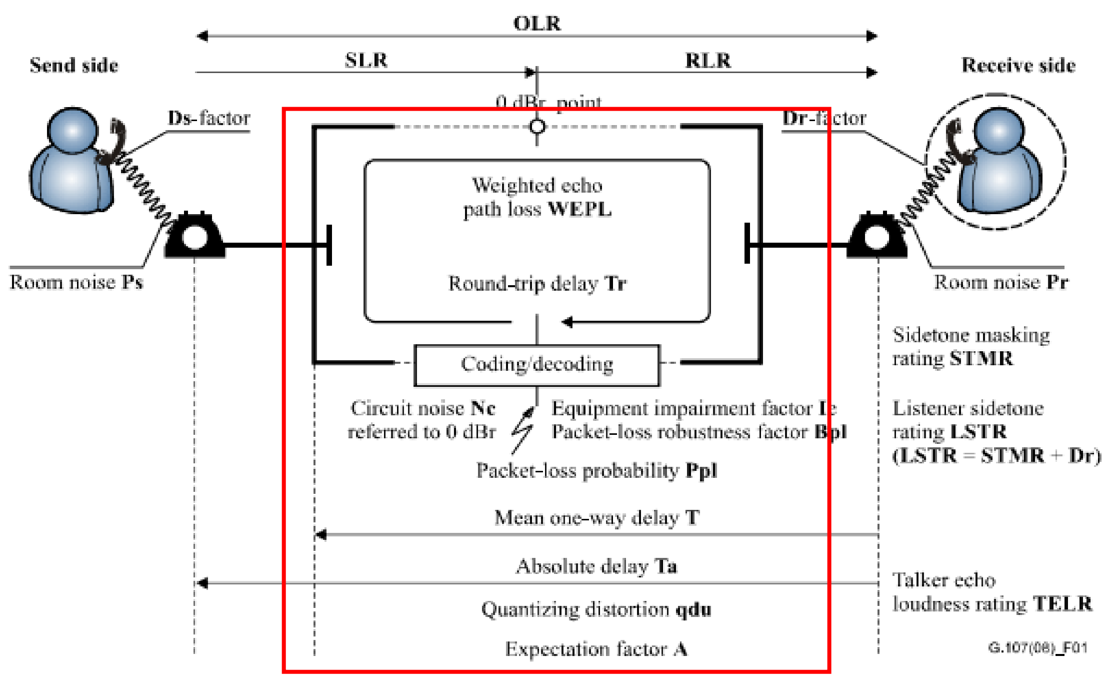


Figure 1 – Reference connection of the E-model

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

7.1 Calculation of the transmission rating factor, R

According to the equipment impairment factor method, the fundamental principle of the E-model is based on a concept given in the description of the OPINE model (see [b-ITU-T P-Sup.3]).

Psychological factors on the psychological scale are additive.

The result of any calculation with the E-model in a first step is a transmission rating factor *R*, which combines all transmission parameters relevant for the considered connection. This rating factor *R* is composed of:

$$R = Ro - Is - Id - Ie\text{-}eff + A \qquad (7\text{-}1)$$

Ro represents in principle the basic signal-to-noise ratio, including noise sources such as circuit noise and room noise. Factor *Is* is a combination of all impairments which occur more or less simultaneously with the voice signal. Factor *Id* represents the impairments caused by delay and the effective equipment impairment factor *Ie-eff* represents impairments caused by low bit-rate codecs. It also includes impairment due to randomly distributed packet losses. The advantage factor *A* allows for compensation of impairment factors when the user benefits from other types of access to the user. The term *Ro* and the *Is* and *Id* values are subdivided into further specific impairment values. The following clauses give the equations used in the E-model.

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

An estimated mean opinion score (MOS_{CQE}) for the conversational situation in the scale 1-5 can be obtained from the *R*-factor using the equations:

For $R < 0$: $MOS_{CQE} = 1$

For $0 < R < 100$: $MOS_{CQE} = 1 + 0.035R + R(R-60)(100-R)7 \cdot 10^{-6}$ (B-4)

For $R > 100$: $MOS_{CQE} = 4.5$

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

In some cases, transmission planners may not be familiar with the use of quality measures such as the *R* rating factor obtained from planning calculations, and thus provisional guidance for interpreting calculated *R* factors for planning purposes is given in Table B.1[3]. This table also contains equivalent transformed values of *R* into estimated conversational MOS_{CQE}, GoB and PoW.

Table B.1 – Provisional guide for the relation between *R*-value and user satisfaction

***R*-value (lower limit)**	**MOS_{CQE} (lower limit)**	**GoB (%) (lower limit)**	**PoW (%) (upper limit)**	**User satisfaction**
90	4.34	97	~0	Very satisfied
80	4.03	89	~0	Satisfied
70	3.60	73	6	Some users dissatisfied
60	3.10	50	17	Many users dissatisfied
50	2.58	27	38	Nearly all users dissatisfied

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

7.2.3 MOS-CQE

The score is calculated by a network planning model which aims at predicting the quality in a conversational application situation. Estimates of conversational quality carried out according to [ITU-T G.107], when transformed to mean opinion score, give results in terms of MOS-CQE.

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-P.800.1-201607-I!!PDF-E&type=items)

18. The methods practiced by TI's use of the accused products include receiving, by the network device, one or more second packetized audio messages and evaluating, by the network device, at least portions of one or more of the one or more second packetized audio messages to obtain measurements associated with the plurality of characteristics. For example, the accused products are used by TI to implement the ITU-T G.107 Recommendation. The E-model is applied to a real-time voice call ("second packetized audio messages") for measuring its voice quality by calculating the R value. The R value can be converted into a MOS value. The R value represents the combinational effect of all transmission parameters in an audio conversation. The E-Model estimates the MOS-CQE/audio quality of the speech signals.

7.1 Calculation of the transmission rating factor, R

According to the equipment impairment factor method, the fundamental principle of the E-model is based on a concept given in the description of the OPINE model (see [b-ITU-T P-Sup.3]).

Psychological factors on the psychological scale are additive.

The result of any calculation with the E-model in a first step is a transmission rating factor *R*, which combines all transmission parameters relevant for the considered connection. This rating factor *R* is composed of:

$$R = Ro - Is - Id - Ie\text{-}eff + A \qquad (7\text{-}1)$$

Ro represents in principle the basic signal-to-noise ratio, including noise sources such as circuit noise and room noise. Factor *Is* is a combination of all impairments which occur more or less simultaneously with the voice signal. Factor *Id* represents the impairments caused by delay and the effective equipment impairment factor *Ie-eff* represents impairments caused by low bit-rate codecs. It also includes impairment due to randomly distributed packet losses. The advantage factor *A* allows for compensation of impairment factors when the user benefits from other types of access to the user. The term *Ro* and the *Is* and *Id* values are subdivided into further specific impairment values. The following clauses give the equations used in the E-model.

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

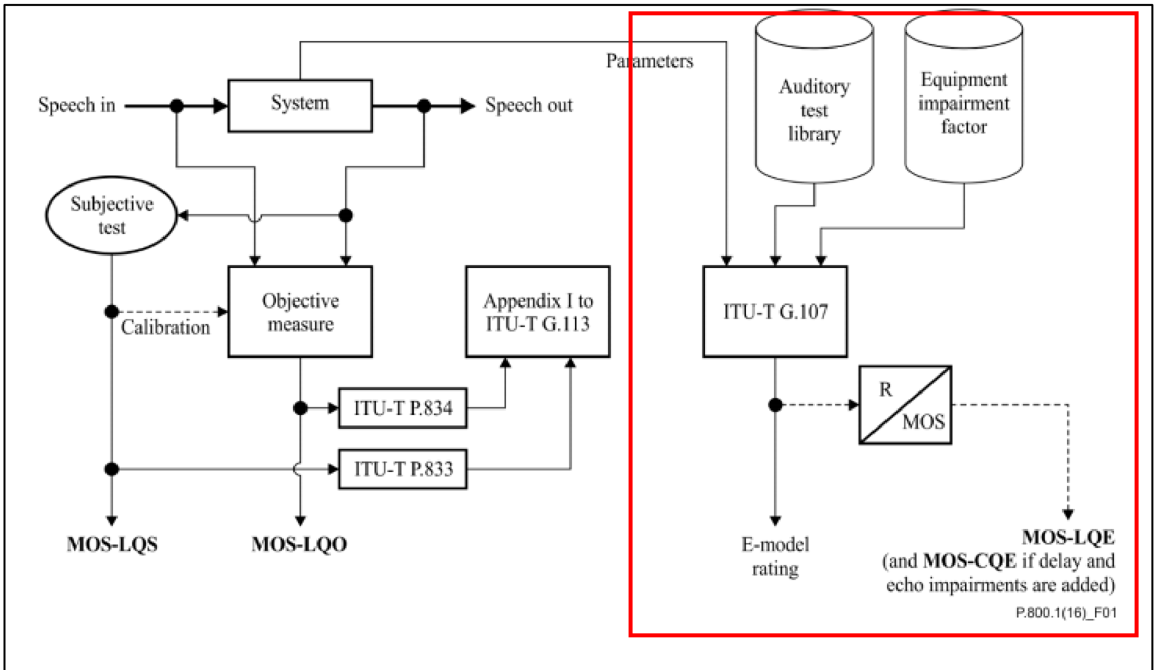
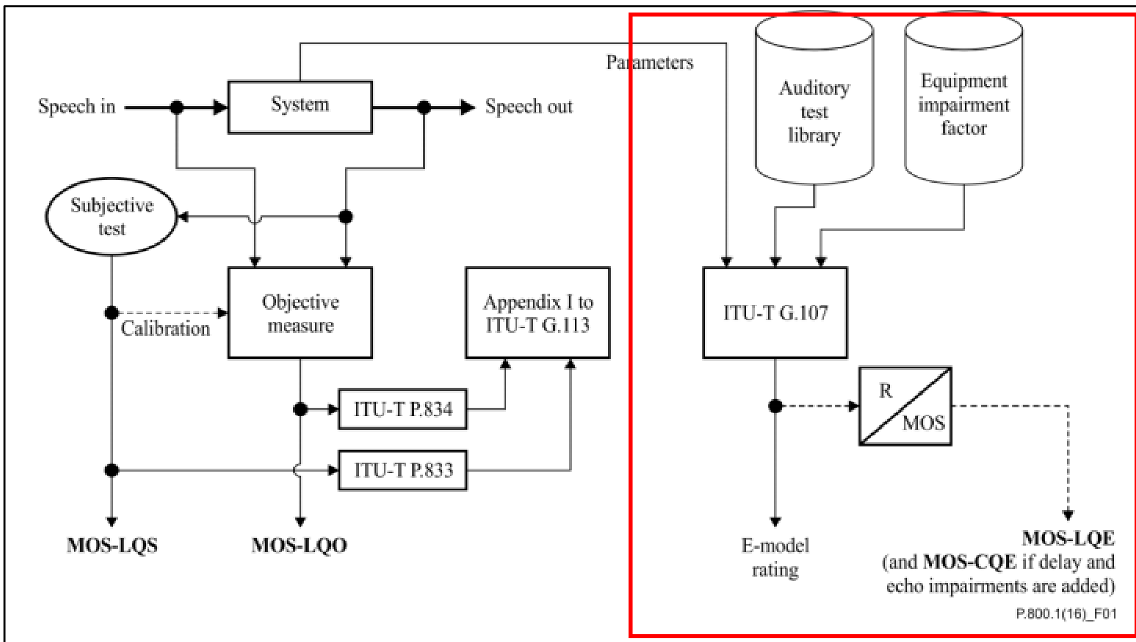


Figure 1 – Relationship between some audio MOS qualifiers

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-P.800.1-201607-I!!PDF-E&type=items)

19. The methods practiced by TI's use of the accused products include creating, by the network device, a test matrix using the obtained measurements and comparing, by the network device, the test matrix and the reference matrix to predict a quality level associated with the one or more second packetized audio messages. For example, the accused products are used by TI to implement the ITU-T G.107 Recommendation. ITU-T G.107 E-Model estimates MOS-CQE/audio quality of the speech signals. The test speech signal parameters are input to the G.107 E-Model for calculating the R and MOS values. The calculated R/MOS value ("test matrix") is then compared with the reference table ("reference matrix") for determining the perceived audio quality. For example, a comparison is performed between estimated MOS value and existing reference values to determine the perceived audio quality of the test speech. For instance, a MOS value of 4.5 and a R value of 95 is compared with each row of the reference table and a perceived voice quality is determined accordingly, which is Best/Very satisfied in this case.



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(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

Table 1 - Definition of categories of speech transmission quality

Range of E-model Rating R	Speech transmission quality category	User satisfaction
90 ≤ R < 100	Best	Very satisfied
80 ≤ R < 90	High	Satisfied
70 ≤ R < 80	Medium	Some users dissatisfied
60 ≤ R < 70	Low	Many users dissatisfied
50 ≤ R < 60	Poor	Nearly all users dissatisfied

NOTE 1 – Connections with E-model Ratings R below 50 are not recommended.
NOTE 2 – Although the trend in transmission planning is to use E-model Ratings R, equations to convert E-model Ratings R into other metrics, e.g. %MOS, %GoB, PoW can be found in **ITU-T Rec. G.107 Annex B** [1].

(Source: https://www.itu.int/ITU-T/studygroups/com12/emodelv1/tut.htm)

20. TI has infringed the '105 Patent by making, having made, using, importing, providing, supplying, distributing, selling or offering for sale products including the claimed non-transitory computer-readable medium having instructions stored thereon configured to cause a computing device to perform operations, and those operations including obtaining a reference matrix based on estimates of perceived audio quality of at least portions of one or more first packetized audio messages, the reference matrix modeling values of a plurality of characteristics associated with a particular quality level. For example, the accused products are configured to be used to implement the ITU-T G.107 Recommendation. The quality of audio in VoIP networks (packet switched networks) is calculated using MOS (Mean Opinion score) values according to ITU-T G.107 Recommendation E-model. The E-model computes a transmission rating value R, which is a combinational effect of all the transmission parameters in an audio conversation. The E-model uses a reference table ("reference matrix") based on the estimates of perceived audio conversational/audio quality. The reference table includes modelling values like MOS-CQE (Mean Opinion Score – Estimated Conversational Quality), each associated with a quality level.

7 Target services

This Recommendation gives guidelines for QoE assessment of various telecommunication services mainly utilizing audio and visual media.

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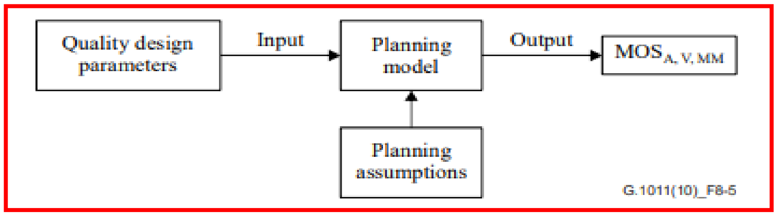

Figure 8-5 – Planning model

Standard examples of such models are [ITU-T G.107] for speech and [ITU-T G.1070] for videophone.

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-G.1011-201506-S!!PDF-E&type=items)

Recommendation ITU-T G.107

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1 Scope

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(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

7 Structure and basic algorithms of the E-model

The E-model is based on the equipment impairment factor method, following previous transmission rating models. It was developed by an ETSI ad hoc group called "Voice Transmission Quality from Mouth to Ear".

The reference connection, as shown in Figure 1, is split into a send side and a receive side. The model estimates the conversational quality from mouth to ear as perceived by the user at the receive side, both as listener and talker.

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

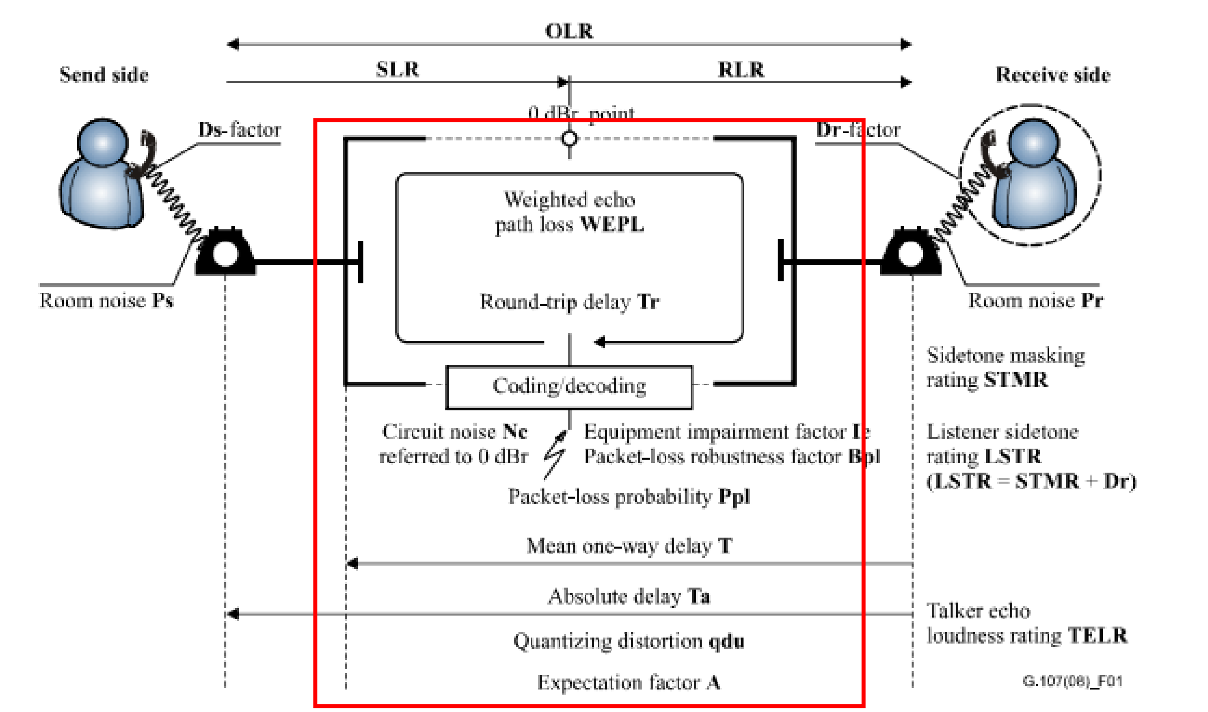

Figure 1 – Reference connection of the E-model

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

7.1 Calculation of the transmission rating factor, R

According to the equipment impairment factor method, the fundamental principle of the E-model is based on a concept given in the description of the OPINE model (see [b-ITU-T P-Sup.3]).

Psychological factors on the psychological scale are additive.

The result of any calculation with the E-model in a first step is a transmission rating factor *R*, which combines all transmission parameters relevant for the considered connection. This rating factor *R* is composed of:

$$R = Ro - Is - Id - Ie\text{-}eff + A \qquad (7\text{-}1)$$

Ro represents in principle the basic signal-to-noise ratio, including noise sources such as circuit noise and room noise. Factor *Is* is a combination of all impairments which occur more or less simultaneously with the voice signal. Factor *Id* represents the impairments caused by delay and the effective equipment impairment factor *Ie-eff* represents impairments caused by low bit-rate codecs. It also includes impairment due to randomly distributed packet losses. The advantage factor *A* allows for compensation of impairment factors when the user benefits from other types of access to the user. The term *Ro* and the *Is* and *Id* values are subdivided into further specific impairment values. The following clauses give the equations used in the E-model.

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

An estimated mean opinion score (MOS_{CQE}) for the conversational situation in the scale 1-5 can be obtained from the R-factor using the equations:

For $R < 0$: $MOS_{CQE} = 1$

For $0 < R < 100$: $MOS_{CQE} = 1 + 0.035R + R(R - 60)(100 - R)7 \cdot 10^{-6}$ (B-4)

For $R > 100$: $MOS_{CQE} = 4.5$

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

In some cases, transmission planners may not be familiar with the use of quality measures such as the R rating factor obtained from planning calculations, and thus provisional guidance for interpreting calculated R factors for planning purposes is given in Table B.1[3]. This table also contains equivalent transformed values of R into estimated conversational MOS_{CQE}, GoB and PoW.

Table B.1 – Provisional guide for the relation between *R*-value and user satisfaction

***R*-value (lower limit)**	**MOS_{CQE} (lower limit)**	**GoB (%) (lower limit)**	**PoW (%) (upper limit)**	**User satisfaction**
90	4.34	97	~0	Very satisfied
80	4.03	89	~0	Satisfied
70	3.60	73	6	Some users dissatisfied
60	3.10	50	17	Many users dissatisfied
50	2.58	27	38	Nearly all users dissatisfied

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

7.2.3 MOS-CQE

The score is calculated by a network planning model which aims at predicting the quality in a conversational application situation. Estimates of conversational quality carried out according to [ITU-T G.107], when transformed to mean opinion score, give results in terms of MOS-CQE.

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-P.800.1-201607-I!!PDF-E&type=items)

21. The operations performed by the accused products include creating a test matrix using measurements of at least portions of one or more second packetized audio messages associated with the plurality of characteristics and predicting a quality level associated with the

at least portions of one or more second packetized audio messages by comparing the test matrix to the reference matrix. For example, the accused products are configured to be used to implement the ITU-T G.107 Recommendation. The E-model is applied to a real-time voice call ("second packetized audio messages") for measuring its voice quality by calculating the R value. The R value can be converted into a MOS value. The R value represents the combinational effect of all transmission parameters in an audio conversation. ITU-T G.107 E-Model estimates MOS-CQE/audio quality of the speech signals. The test speech signal parameters are input to the G.107 E model for calculating the R and MOS values. The calculated R/MOS value ("test matrix") is then compared with the reference table ("reference matrix") for determining the perceived audio quality. For example, a comparison is performed between estimated MOS value and existing reference values to determine the perceived audio quality of the test speech. For instance, a MOS value of 4.5 and a R value of 95 would be compared with each row of the reference table and a perceived voice quality is determined accordingly, which is Best/Very satisfied in this case.

7.1 Calculation of the transmission rating factor, R

According to the equipment impairment factor method, the fundamental principle of the E-model is based on a concept given in the description of the OPINE model (see [b-ITU-T P-Sup.3]).

Psychological factors on the psychological scale are additive.

The result of any calculation with the E-model in a first step is a transmission rating factor *R*, which combines all transmission parameters relevant for the considered connection. This rating factor *R* is composed of:

$$R = Ro - Is - Id - Ie\text{-}eff + A \qquad (7\text{-}1)$$

Ro represents in principle the basic signal-to-noise ratio, including noise sources such as circuit noise and room noise. Factor *Is* is a combination of all impairments which occur more or less simultaneously with the voice signal. Factor *Id* represents the impairments caused by delay and the effective equipment impairment factor *Ie-eff* represents impairments caused by low bit-rate codecs. It also includes impairment due to randomly distributed packet losses. The advantage factor *A* allows for compensation of impairment factors when the user benefits from other types of access to the user. The term *Ro* and the *Is* and *Id* values are subdivided into further specific impairment values. The following clauses give the equations used in the E-model.

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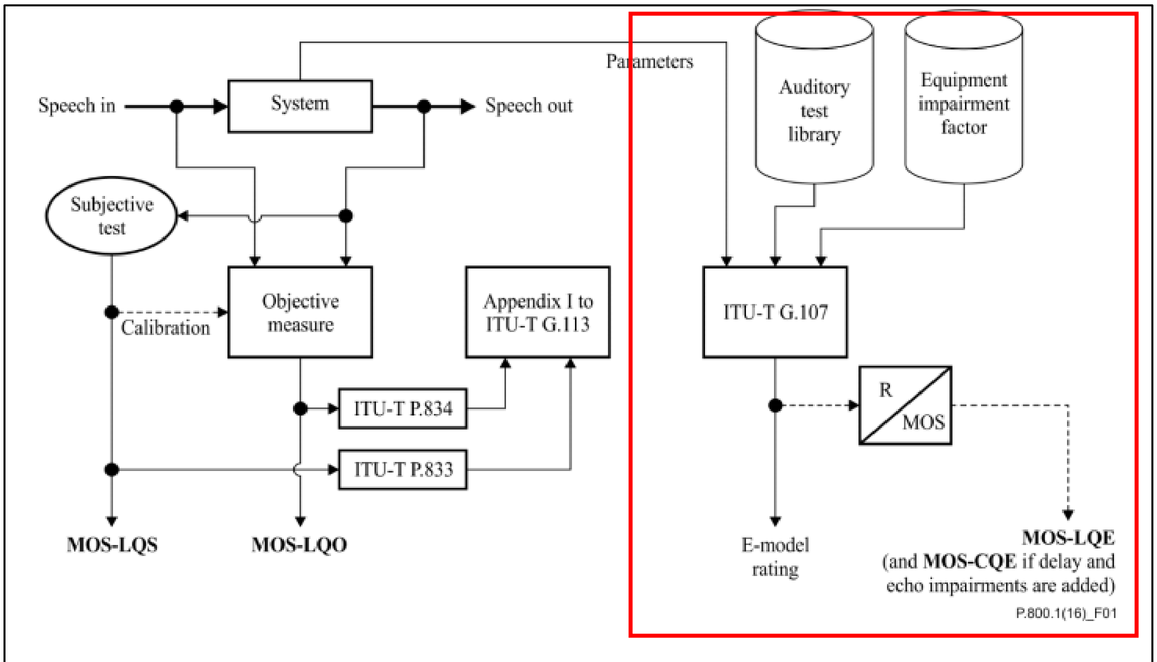

Figure 1 – Relationship between some audio MOS qualifiers

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-P.800.1-201607-I!!PDF-E&type=items)

In some cases, transmission planners may not be familiar with the use of quality measures such as the *R* rating factor obtained from planning calculations, and thus provisional guidance for interpreting calculated *R* factors for planning purposes is given in Table B.1[3]. This table also contains equivalent transformed values of *R* into estimated conversational MOS_{CQE}, GoB and PoW.

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70	3.60	73	6	Some users dissatisfied
60	3.10	50	17	Many users dissatisfied
50	2.58	27	38	Nearly all users dissatisfied

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

Table 1 - Definition of categories of speech transmission quality

Range of E-model Rating R	Speech transmission quality category	User satisfaction
90 ≤ R < 100	Best	Very satisfied
80 ≤ R < 90	High	Satisfied
70 ≤ R < 80	Medium	Some users dissatisfied
60 ≤ R < 70	Low	Many users dissatisfied
50 ≤ R < 60	Poor	Nearly all users dissatisfied
NOTE 1 – Connections with E-model Ratings R below 50 are not recommended. NOTE 2 – Although the trend in transmission planning is to use E-model Ratings R, equations to convert E-model Ratings R into other metrics, e.g. %MOS, %GoB, PoW can be found in **ITU-T Rec. G.107 Annex B** [1].		

(Source: https://www.itu.int/ITU-T/studygroups/com12/emodelv1/tut.htm)

22. TI has had knowledge of the '105 Patent at least as of the date when it was notified of the filing of this action.

23. Far North Patents has been damaged as a result of the infringing conduct by TI alleged above. Thus, TI is liable to Far North Patents in an amount that adequately compensates it for such infringements, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

24. Far North Patents and/or its predecessors-in-interest have satisfied all statutory obligations required to collect pre-filing damages for the full period allowed by law for infringement of the ‘105 Patent.

COUNT II

DIRECT INFRINGEMENT OF U.S. PATENT NO. 8,068,437

25. On November 29, 2011, United States Patent No. 8,068,437 (“the ‘437 Patent”) was duly and legally issued by the United States Patent and Trademark Office for an invention entitled “Determining the Effects of New Types of Impairments on Perceived Quality of a Voice Service.”

26. Far North Patents is the owner of the ‘437 Patent, with all substantive rights in and to that patent, including the sole and exclusive right to prosecute this action and enforce the ‘437 Patent against infringers, and to collect damages for all relevant times.

27. TI made, had made, used, imported, provided, supplied, distributed, sold, and/or offered for sale products and/or systems including, for example, its TI Telogy Software and TI TNETV3020 Carrier Infrastructure Platform families of products that include advanced quality monitoring capabilities (collectively, “accused products”).

Telogy Software™ products for VoIP

TI's Telogy Software products provide the broadest range of VoIP features available. As new TI device architectures evolve, so too do Telogy Software features to take advantage of new system interfaces and performance.

Key software capabilities include:

- Voice processing for PSTN to packet gateway applications
- T.38 fax relay
- Conference bridge
- Signaling
- Voice and call quality management

With the largest installed base of field-hardened gateway-specific solutions since 1995, Telogy Software provides world-class VoIP software solutions that industry giants rely on. Every level of VoIP product benefits from the breadth of the software deployments and improvements.

Voice and call quality management

Fundamental to any communications system is the ability to discover, isolate and remedy problems as quickly as possible to minimize or eliminate the degree to which users are impacted. VoIP networks must support telco-grade management and diagnostics for wide-scale, cost-effective deployments.

TI's voice and call quality management features include:

- Real-time measures such as mean opinion score (MOS) estimation based on delay, jitter and packet loss statistics
- Support for RFC3611 Real-Time Protocol Extended Reports (RTCP XR)
- Detailed call statistics for fax, tone detection, echo, error stats and packet stats
- Diagnostic tools for detailed troubleshooting: trace, fax, echo, TDM or packet interfaces, analog line tests
- Alerts/alarms with configurable thresholds
- Optimized adaptive jitter buffer, packet loss concealment and redundancy

(Source : www.ti.com/lit/ml/spat180a/spat180a.pdf)

TNETV3020

Carrier Infrastructure Platform

Telogy Software™ products integrated with TI's DSP-based high-density communications processor

Texas Instruments

(Source : http://www.ti.com/lit/ml/spat174a/spat174a.pdf)

PIQUA™ technology

The TNETV3020 software includes support for TI's award-winning quality-initiative PIQUA technology. PIQUA technology provides easy access to comprehensive network diagnostics and statistics in a standards-based architecture. This support vastly improves the carrier's ability to find and fix problems within the network and enhance the user's experience. PIQUA technology provides added value for carriers through statistics such as the following:

- Echo Quality Index (EQI) – provides a measure of the propensity for echo on any given conversation
- Packet loss recovery statistics – measures the effectiveness of packet loss recovery mechanisms
- Fax and modem performance indicators
- Customized quality alerts
- Support for RTCP-XR (RFC 3611)
- RTCP-HR

(Source : http://www.ti.com/lit/ml/spat174a/spat174a.pdf)

RFC 3611 RTCP XR November 2003

References

Normative References

[1] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[2] Crocker, D., Ed. and P. Overell, "Augmented BNF for Syntax Specifications: ABNF", RFC 2234, November 1997.

[3] ETSI, "Quality of Service (QoS) measurement methodologies", ETSI TS 101 329-5 V1.1.1 (2000-11), November 2000.

[4] Handley, M. and V. Jacobson, "SDP: Session Description Protocol", RFC 2327, April 1998.

[5] Hovey, R. and S. Bradner, "The Organizations Involved in the IETF Standards Process", BCP 11, RFC 2028, October 1996.

[6] ITU-T, "The E-Model, a computational model for use in transmission planning", Recommendation G.107, January 2003.

[7] Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA Considerations Section in RFCs", BCP 26, RFC 2434, October 1998.

(Source : https://tools.ietf.org/html/rfc3611)

```
MOS-CQ: 8 bits
      The estimated mean opinion score for conversational quality
      (MOS-CQ) is defined as including the effects of delay and other
      effects that would affect conversational quality.  The metric
      may be calculated by converting an R factor determined
      according to ITU-T G.107 [6] or ETSI TS 101 329-5 [3] into an
      estimated MOS using the equation specified in G.107.  It is
      expressed as an integer in the range 10 to 50, corresponding to
      MOS x 10, as for MOS-LQ.

      A value of 127 indicates that this parameter is unavailable.
      Values other than 127 and the valid range defined above MUST
      not be sent and MUST be ignored by the receiving system.
```

(Source : https://tools.ietf.org/html/rfc3611)

28. By doing so, TI has directly infringed (literally and/or under the doctrine of equivalents) at least Claim 9 of the ‘437 Patent. TI’s infringement in this regard is ongoing.

29. TI has infringed the ‘437 Patent by using the accused products and thereby practicing a method performed by a computer system that includes generating, by a processor of the computer system, an assumed model for a second communication service, where the assumed model is used to transform data regarding a first performance characteristic in the second communication service to reflect effects from a second performance characteristic in the second communication service. For example, the accused products are used by TI to implement the ITU-T G.107 Recommendation. The ITU-T G.107 Recommendation includes an E-model for calculating voice quality as perceived by a typical telephone user. The E-model outputs a transmission rating factor i.e., R, which can be transformed into Mean Opinion Score i.e., MOS value that represents the voice quality. The R value combines the effects of all relevant transmission parameters, and comprises of an effective Equipment impairment factor, $I_{e\text{-}eff}$. The E-model is applied to a real-time voice call (“second communication service”) for measuring its voice quality. The effective Equipment impairment factor is calculated using a mathematical algorithm (“assumed model”). The mathematical algorithm includes an addition of two values. The first value is an equipment impairment factor (“first performance characteristic”) at zero

packet loss, or I_e. The I_e values are based on subjective MOS test results and are predefined for different codecs in ITU-T G.113 recommendation. The second value is a computation of different packet-loss-based parameters ("second performance characteristic") namely, a packet loss robustness factor (Bpl), packet loss probability (Ppl) and a burst ratio. Thus, the computed $I_{e\text{-}eff}$ value reflects the effects of packet loss in the voice quality.

The E-model: a computational model for use in transmission planning

1 Scope

This Recommendation describes a computational model, known as the E-model, that has proven useful as a transmission planning tool for assessing the combined effects of variations in several transmission parameters that affect the conversational[1] quality of 3.1 kHz handset telephony. This computational model can be used, for example, by transmission planners to help ensure that users will be satisfied with end-to-end transmission performance whilst avoiding over-engineering of networks. It must be emphasized that the primary output from the model is the "rating factor" *R* but this can be transformed to give estimates of customer opinion. Such estimates are only made for transmission planning purposes and not for actual customer opinion prediction (for which there is no agreed-upon model recommended by the ITU-T).

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

An estimated mean opinion score (MOS_{CQE}) for the conversational situation in the scale 1-5 can be obtained from the *R*-factor using the equations:

For $R < 0$: $MOS_{CQE} = 1$

For $0 < R < 100$: $MOS_{CQE} = 1 + 0.035R + R(R-60)(100-R)7 \cdot 10^{-6}$ (B-4)

For $R > 100$: $MOS_{CQE} = 4.5$

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

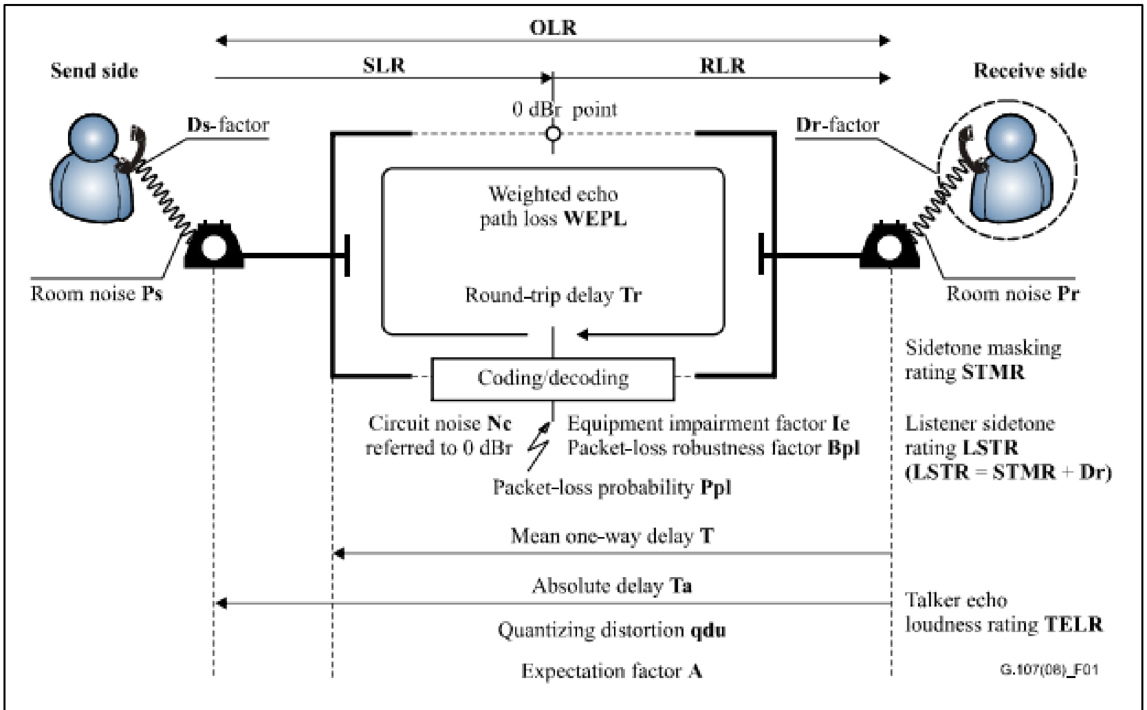

Figure 1 – Reference connection of the E-model

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

7.1 Calculation of the transmission rating factor, R

According to the equipment impairment factor method, the fundamental principle of the E-model is based on a concept given in the description of the OPINE model, see [b-ITU-T P-Sup.3].

Psychological factors on the psychological scale are additive.

The result of any calculation with the E-model in a first step is a transmission rating factor *R*, which combines all transmission parameters relevant for the considered connection. This rating factor *R* is composed of:

$$R = Ro - Is - Id - Ie\text{-}eff + A \qquad (7\text{-}1)$$

Ro represents in principle the basic signal-to-noise ratio, including noise sources such as circuit noise and room noise. Factor *Is* is a combination of all impairments which occur more or less simultaneously with the voice signal. Factor *Id* represents the impairments caused by delay and the effective equipment impairment factor *Ie-eff* represents impairments caused by low bit-rate codecs. It also includes impairment due to randomly distributed packet losses. The advantage factor *A* allows for compensation of impairment factors when the user benefits from other types of access to the user. The term *Ro* and the *Is* and *Id* values are subdivided into further specific impairment values. The following clauses give the equations used in the E-model.

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

7.5 Equipment impairment factor, Ie

The values for the equipment impairment factor *Ie* of elements using low bit-rate codecs are not related to other input parameters. They depend on subjective mean opinion score (MOS) test results as well as on network experience. Refer to Appendix I of [ITU-T G.113] for the currently recommended values of *Ie*.

Specific impairment factor values for codec operation under random[2] packet-loss have formerly been treated using tabulated, packet-loss dependent *Ie*-values. Now, the packet-loss robustness factor *Bpl* is defined as a codec-specific value. The packet-loss dependent effective equipment impairment factor *Ie-eff* is derived using the codec-specific value for the equipment impairment factor at zero packet-loss *Ie* and the packet-loss robustness factor *Bpl*, both listed in Appendix I of [ITU-T G.113] for several codecs. With the packet-loss probability *Ppl*, *Ie-eff* is calculated using the equation:

$$Ie\text{-}eff = Ie + (95 - Ie) \cdot \frac{Ppl}{\frac{Ppl}{BurstR} + Bpl} \quad (7\text{-}29)$$

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

This appendix provides up-to-date information on available values of the equipment impairment factor, *Ie*, and packet-loss robustness factor, *Bpl*, for codecs or codec families. It is intended to be updated regularly.

Table I.1 provides provisional planning values for the equipment impairment factor, *Ie*. These *Ie* values refer to non-error conditions without propagation errors, frame-erasures or packet loss. Subsequent tables deal with error and various loss conditions.

Table I.1 – Provisional planning values for the equipment impairment factor, *Ie*

Codec type	Reference	Operating rate [kbit/s]	*Ie* value
PCM (see Note)	G.711	64	0
ADPCM	G.726, G.727	40	2
	G.721, G.726, G.727	32	7
	G.726, G.727	24	25
	G.726, G.727	16	50

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-G.113-200711-I!!PDF-E&type=items)

30. The methods practiced by TI's use of the accused products include establishing, by the processor, a communication session via the second communication service and obtaining,

by the processor, subjective ratings of the first performance characteristic in the second communication service using the established communication session. For example, the accused products are used by TI to implement the ITU-T G.107 Recommendation. The E-model is applied to a real-time voice call session over a system including the accused products ("second communication service") for measuring the call's voice quality by calculating the R value. The R value comprises of an effective Equipment impairment factor, $I_{e\text{-}eff}$ which is calculated using various parameters like an equipment impairment factor at zero packet loss I_e ("first performance characteristic"), and other packet loss based parameters. The I_e values ("subjective ratings") are derived from the results of subjective listening-only tests and are used as an input to the E-Model. They can be obtained from predefined values based on the implemented codec.

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The result of any calculation with the E-model in a first step is a transmission rating factor *R*, which combines all transmission parameters relevant for the considered connection. This rating factor *R* is composed of:

$$R = Ro - Is - Id - Ie\text{-}eff + A \quad (7\text{-}1)$$

Ro represents in principle the basic signal-to-noise ratio, including noise sources such as circuit noise and room noise. Factor *Is* is a combination of all impairments which occur more or less simultaneously with the voice signal. Factor *Id* represents the impairments caused by delay and the effective equipment impairment factor *Ie-eff* represents impairments caused by low bit-rate codecs. It also includes impairment due to randomly distributed packet losses. The advantage factor *A* allows for compensation of impairment factors when the user benefits from other types of access to the user. The term *Ro* and the *Is* and *Id* values are subdivided into further specific impairment values. The following clauses give the equations used in the E-model.

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$$Ie\text{-}eff = Ie + (95 - Ie) \cdot \frac{Ppl}{\frac{Ppl}{BurstR} + Bpl} \qquad (7\text{-}29)$$

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31. The methods practiced by TI's use of the accused products include generating, by the processor, altered subjective ratings using the assumed model to reflect effects of the second

performance characteristic on the subjective ratings. For example, the accused products are used by TI to implement the ITU-T G.107 Recommendation. The effective equipment impairment factor $I_{e\text{-eff}}$ is calculated using a mathematical algorithm ("assumed model"). The mathematical algorithm includes an addition of two values. The first value is an equipment impairment factor ("first performance characteristic") at zero packet loss i.e., I_e. The I_e values are based on subjective MOS test results and are predefined for different codecs in ITU-T G.113 recommendation. The second value is a computation of different packet loss ("second performance characteristic") based parameters namely, a packet loss robustness factor (Bpl), packet loss probability (Ppl) and a burst ratio. Thus, the computed $I_{e\text{-eff}}$ value reflects the effects of packet loss on the equipment impairment factor at zero packet loss.

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7.5 Equipment impairment factor, Ie

The values for the equipment impairment factor *Ie* of elements using low bit-rate codecs are not related to other input parameters. They depend on subjective mean opinion score (MOS) test results as well as on network experience. Refer to Appendix I of [ITU-T G.113] for the currently recommended values of *Ie*.

Specific impairment factor values for codec operation under random[2] packet-loss have formerly been treated using tabulated, packet-loss dependent *Ie*-values. Now, the packet-loss robustness factor *Bpl* is defined as a codec-specific value. The packet-loss dependent effective equipment impairment factor *Ie-eff* is derived using the codec-specific value for the equipment impairment factor at zero packet-loss *Ie* and the packet-loss robustness factor *Bpl*, both listed in Appendix I of [ITU-T G.113] for several codecs. With the packet-loss probability *Ppl*, *Ie-eff* is calculated using the equation:

$$Ie\text{-}eff = Ie + (95 - Ie) \cdot \frac{Ppl}{\frac{Ppl}{BurstR} + Bpl} \qquad (7\text{-}29)$$

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

This appendix provides up-to-date information on available values of the equipment impairment factor, *Ie*, and packet-loss robustness factor, *Bpl*, for codecs or codec families. It is intended to be updated regularly.

Table I.1 provides provisional planning values for the equipment impairment factor, *Ie*. These *Ie* values refer to non-error conditions without propagation errors, frame-erasures or packet loss. Subsequent tables deal with error and various loss conditions.

Table I.1 – Provisional planning values for the equipment impairment factor, *Ie*

Codec type	Reference	Operating rate [kbit/s]	*Ie* value
PCM (see Note)	G.711	64	0
ADPCM	G.726, G.727	40	2
	G.721, G.726, G.727	32	7
	G.726, G.727	24	25
	G.726, G.727	16	50

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-G.113-200711-I!!PDF-E&type=items)

32. The methods practiced by TI's use of the accused products include generating, by the processor, quality index values from the altered subjective ratings. For example, the accused

products are used by TI to implement the ITU-T G.107 Recommendation. The MOS_{CQE} values are calculated using the R values. The R value is calculated using various parameters which includes the effective equipment impairment factor $I_{e\text{-}eff}$ ("altered subjective rating").

> **7.1 Calculation of the transmission rating factor, R**
>
> According to the equipment impairment factor method, the fundamental principle of the E-model is based on a concept given in the description of the OPINE model, see [b-ITU-T P-Sup.3].
>
> Psychological factors on the psychological scale are additive.
>
> The result of any calculation with the E-model in a first step is a transmission rating factor *R*, which combines all transmission parameters relevant for the considered connection. This rating factor *R* is composed of:
>
> $$R = Ro - Is - Id - Ie\text{-}eff + A \quad (7\text{-}1)$$
>
> *Ro* represents in principle the basic signal-to-noise ratio, including noise sources such as circuit noise and room noise. Factor *Is* is a combination of all impairments which occur more or less simultaneously with the voice signal. Factor *Id* represents the impairments caused by delay and the effective equipment impairment factor *Ie-eff* represents impairments caused by low bit-rate codecs. It also includes impairment due to randomly distributed packet losses. The advantage factor *A* allows for compensation of impairment factors when the user benefits from other types of access to the user. The term *Ro* and the *Is* and *Id* values are subdivided into further specific impairment values. The following clauses give the equations used in the E-model.

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

> An estimated mean opinion score (MOS_{CQE}) for the conversational situation in the scale 1-5 can be obtained from the *R*-factor using the equations:
>
> For $R < 0$: $MOS_{CQE} = 1$
>
> For $0 < R < 100$: $MOS_{CQE} = 1 + 0.035R + R(R-60)(100-R)7 \cdot 10^{-6}$ (B-4)
>
> For $R > 100$: $MOS_{CQE} = 4.5$

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

33. The methods practiced by TI's use of the accused products include comparing, by the processor, the generated quality index values to quality index values of a first communication service and determining, by the processor, whether the quality of the second communication

service is comparable to a quality of the first communication service based on the comparison. For example, the accused products are used by TI to implement the ITU-T G.107 Recommendation. The E-model is based on modeling the results from multiple subjective tests performed on a wide range of transmission parameters. It also includes a reference table with different R value and MOS value thresholds, and corresponding perceived voice quality. The MOS values (quality index) in the reference table are obtained using an aggregate of multiple test calls' ("first communication service") data. The computed MOS value is then compared with the reference table. Based on the comparison, it is determined whether the computed MOS value is comparable to the reference MOS value—e.g., whether the second communication service is expected to fall into the same user satisfaction category as the first communication service.

The E-model (**ITU-T Rec. G.107** [1]) is a transmission planning tool that provides a prediction of the expected voice quality, as perceived by a typical telephone user, for a complete end-to-end (i.e. mouth-to-ear) telephone connection under conversational conditions. The E-model takes into account a wide range of telephony-band impairments, in particular the impairment due to low bit-rate coding devices and one-way delay, as well as the "classical" telephony impairments of loss, noise and echo. It can be applied to assess the voice quality of wireline and wireless scenarios, based on circuit-switched and packet-switched technology.

The E-model is based on modeling the results from a large number of subjective tests done in the past on a wide range of transmission parameters. The primary output of the E-model calculations is a scalar quality rating value known as the "Transmission Rating Factor, R". R can be transformed into other quality measures such as Mean Opinion Score (MOS-CQE [2]), Percentage Good or Better ((GoB) or Percentage Poor or Worse ((PoW). However, caution should be exercised when comparing these transformed measures with values of MOS, %GoB or %PoW from other sources, which may not have been obtained under comparable conditions.

(Source: https://www.itu.int/ITU-T/studygroups/com12/emodelv1/tut.htm)

Table B.1 – Provisional guide for the relation between *R*-value and user satisfaction

R-value (lower limit)	MOS_{CQE} (lower limit)	GoB (%) (lower limit)	PoW (%) (upper limit)	User satisfaction
90	4.34	97	~0	Very satisfied
80	4.03	89	~0	Satisfied
70	3.60	73	6	Some users dissatisfied
60	3.10	50	17	Many users dissatisfied
50	2.58	27	38	Nearly all users dissatisfied

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

An estimated mean opinion score (MOS_{CQE}) for the conversational situation in the scale 1-5 can be obtained from the R-factor using the equations:

For $R < 0$: $MOS_{CQE} = 1$

For $0 < R < 100$: $MOS_{CQE} = 1 + 0.035R + R(R-60)(100-R)7 \cdot 10^{-6}$ (B-4)

For $R > 100$: $MOS_{CQE} = 4.5$

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

Table 1 - Definition of categories of speech transmission quality

Range of E-model Rating R	Speech transmission quality category	User satisfaction
90 ≤ R < 100	Best	Very satisfied
80 ≤ R < 90	High	Satisfied
70 ≤ R < 80	Medium	Some users dissatisfied
60 ≤ R < 70	Low	Many users dissatisfied
50 ≤ R < 60	Poor	Nearly all users dissatisfied
NOTE 1 – Connections with E-model Ratings R below 50 are not recommended. NOTE 2 – Although the trend in transmission planning is to use E-model Ratings R, equations to convert E-model Ratings R into other metrics, e.g. %MOS, %GoB, PoW can be found in **ITU-T Rec. G.107 Annex B** [1].		

(Source: https://www.itu.int/ITU-T/studygroups/com12/emodelv1/tut.htm)

34. Far North Patents only asserts method claims from the '437 Patent.

35. TI has had knowledge of the '437 Patent at least as of the date when it was notified of the filing of this action.

36. Far North Patents has been damaged as a result of the infringing conduct by TI alleged above. Thus, TI is liable to Far North Patents in an amount that adequately compensates it for such infringements, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

37. Far North Patents and/or its predecessors-in-interest have satisfied all statutory obligations required to collect pre-filing damages for the full period allowed by law for infringement of the '437 Patent.

COUNT III

DIRECT INFRINGEMENT OF U.S. PATENT NO. 7,085,230

38. On August 1, 2006, United States Patent No. 7,085,230 ("the '230 Patent") was duly and legally issued by the United States Patent and Trademark Office for an invention entitled "Method and System for Evaluating the Quality of Packet-Switched Voice Signals."

39. Far North Patents is the owner of the '230 Patent, with all substantive rights in and to that patent, including the sole and exclusive right to prosecute this action and enforce the '230 Patent against infringers, and to collect damages for all relevant times.

40. TI made, had made, used, imported, provided, supplied, distributed, sold, and/or offered for sale products and/or systems including, for example, its TI Telogy Software and TI TNETV3020 Carrier Infrastructure Platform families of products that include advanced quality monitoring capabilities (collectively, "accused products").

Telogy Software™ products for VoIP

TI's Telogy Software products provide the broadest range of VoIP features available. As new TI device architectures evolve, so too do Telogy Software features to take advantage of new system interfaces and performance.

Key software capabilities include:

- Voice processing for PSTN to packet gateway applications
- T.38 fax relay
- Conference bridge
- Signaling
- Voice and call quality management

With the largest installed base of field-hardened gateway-specific solutions since 1995, Telogy Software provides world-class VoIP software solutions that industry giants rely on. Every level of VoIP product benefits from the breadth of the software deployments and improvements.

Voice and call quality management

Fundamental to any communications system is the ability to discover, isolate and remedy problems as quickly as possible to minimize or eliminate the degree to which users are impacted. VoIP networks must support telco-grade management and diagnostics for wide-scale, cost-effective deployments.

TI's voice and call quality management features include:

- Real-time measures such as mean opinion score (MOS) estimation based on delay, jitter and packet loss statistics
- Support for RFC3611 Real-Time Protocol Extended Reports (RTCP XR)
- Detailed call statistics for fax, tone detection, echo, error stats and packet stats
- Diagnostic tools for detailed troubleshooting: trace, fax, echo, TDM or packet interfaces, analog line tests
- Alerts/alarms with configurable thresholds
- Optimized adaptive jitter buffer, packet loss concealment and redundancy

(Source : www.ti.com/lit/ml/spat180a/spat180a.pdf)

TNETV3020

Carrier Infrastructure Platform

Telogy Software™ products integrated with TI's DSP-based high-density communications processor

Texas Instruments

(Source : http://www.ti.com/lit/ml/spat174a/spat174a.pdf)

PIQUA™ technology

The TNETV3020 software includes support for TI's award-winning quality-initiative PIQUA technology. PIQUA technology provides easy access to comprehensive network diagnostics and statistics in a standards-based architecture. This support vastly improves the carrier's ability to find and fix problems within the network and enhance the user's experience. PIQUA technology provides added value for carriers through statistics such as the following:

- Echo Quality Index (EQI) – provides a measure of the propensity for echo on any given conversation
- Packet loss recovery statistics – measures the effectiveness of packet loss recovery mechanisms
- Fax and modem performance indicators
- Customized quality alerts
- Support for RTCP-XR (RFC 3611)
- RTCP-HR

(Source : http://www.ti.com/lit/ml/spat174a/spat174a.pdf)

```
RFC 3611                        RTCP XR                    November 2003

References

Normative References

   [1]  Bradner, S., "Key words for use in RFCs to Indicate Requirement
        Levels", BCP 14, RFC 2119, March 1997.

   [2]  Crocker, D., Ed. and P. Overell, "Augmented BNF for Syntax
        Specifications: ABNF", RFC 2234, November 1997.

   [3]  ETSI, "Quality of Service (QoS) measurement methodologies", ETSI
        TS 101 329-5 V1.1.1 (2000-11), November 2000.

   [4]  Handley, M. and V. Jacobson, "SDP: Session Description
        Protocol", RFC 2327, April 1998.

   [5]  Hovey, R. and S. Bradner, "The Organizations Involved in the
        IETF Standards Process", BCP 11, RFC 2028, October 1996.

   [6]  ITU-T, "The E-Model, a computational model for use in
        transmission planning", Recommendation G.107, January 2003.

   [7]  Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA
        Considerations Section in RFCs", BCP 26, RFC 2434, October 1998.
```

(Source : https://tools.ietf.org/html/rfc3611)

```
MOS-CQ: 8 bits
      The estimated mean opinion score for conversational quality
      (MOS-CQ) is defined as including the effects of delay and other
      effects that would affect conversational quality.  The metric
      may be calculated by converting an R factor determined
      according to ITU-T G.107 [6] or ETSI TS 101 329-5 [3] into an
      estimated MOS using the equation specified in G.107.  It is
      expressed as an integer in the range 10 to 50, corresponding to
      MOS x 10, as for MOS-LQ.

      A value of 127 indicates that this parameter is unavailable.
      Values other than 127 and the valid range defined above MUST
      not be sent and MUST be ignored by the receiving system.
```

(Source : https://tools.ietf.org/html/rfc3611)

41. By doing so, TI has directly infringed (literally and/or under the doctrine of equivalents) at least Claim 1 of the '230 Patent. TI's infringement in this regard is ongoing.

42. TI has infringed the '230 Patent by using the accused products and thereby practicing a method for determining acceptability of quality of a second communications service, in comparison to a first communications service which is deemed to exhibit acceptable quality.

For example, the accused products are used by TI to implement the ITU-T G.107 Recommendation. The ITU-T G.107 Recommendation includes an E-model for calculating voice quality as perceived by a typical telephone user. The E-model outputs a transmission rating factor i.e., R, which can be transformed into Mean Opinion Score—i.e., MOS value—that represents the voice quality. This E-model is applied to a real-time voice call ("second communication service") for measuring its voice quality. The E-model is based on modeling the results from multiple subjective tests performed on a wide range of transmission parameters. It also includes a reference table with different R value and MOS value thresholds, and corresponding perceived voice quality. The MOS values (quality index) in the reference table are obtained using an aggregate of data from multiple test calls using a first communication service. A MOS value of 4.34 and above, or an R value of 90 and above is considered to be very satisfied ("acceptable quality").

The E-model: a computational model for use in transmission planning

1 Scope

This Recommendation describes a computational model, known as the E-model, that has proven useful as a transmission planning tool for assessing the combined effects of variations in several transmission parameters that affect the conversational[1] quality of 3.1 kHz handset telephony. This computational model can be used, for example, by transmission planners to help ensure that users will be satisfied with end-to-end transmission performance whilst avoiding over-engineering of networks. It must be emphasized that the primary output from the model is the "rating factor" *R* but this can be transformed to give estimates of customer opinion. Such estimates are only made for transmission planning purposes and not for actual customer opinion prediction (for which there is no agreed-upon model recommended by the ITU-T).

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

An estimated mean opinion score (MOS_{CQE}) for the conversational situation in the scale 1-5 can be obtained from the R-factor using the equations:

For $R < 0$: $$MOS_{CQE} = 1$$

For $0 < R < 100$: $$MOS_{CQE} = 1 + 0.035R + R(R-60)(100-R)7 \cdot 10^{-6} \quad \text{(B-4)}$$

For $R > 100$: $$MOS_{CQE} = 4.5$$

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

The E-model (**ITU-T Rec. G.107** [1]) is a transmission planning tool that provides a prediction of the expected voice quality, as perceived by a typical telephone user, for a complete end-to-end (i.e. mouth-to-ear) telephone connection under conversational conditions. The E-model takes into account a wide range of telephony-band impairments, in particular the impairment due to low bit-rate coding devices and one-way delay, as well as the "classical" telephony impairments of loss, noise and echo. It can be applied to assess the voice quality of wireline and wireless scenarios, based on circuit-switched and packet-switched technology.

The E-model is based on modeling the results from a large number of subjective tests done in the past on a wide range of transmission parameters. The primary output of the E-model calculations is a scalar quality rating value known as the "Transmission Rating Factor, R". R can be transformed into other quality measures such as Mean Opinion Score (MOS-CQE [2]), Percentage Good or Better ((GoB) or Percentage Poor or Worse ((PoW). However, caution should be exercised when comparing these transformed measures with values of MOS, %GoB or %PoW from other sources, which may not have been obtained under comparable conditions.

(Source: https://www.itu.int/ITU-T/studygroups/com12/emodelv1/tut.htm)

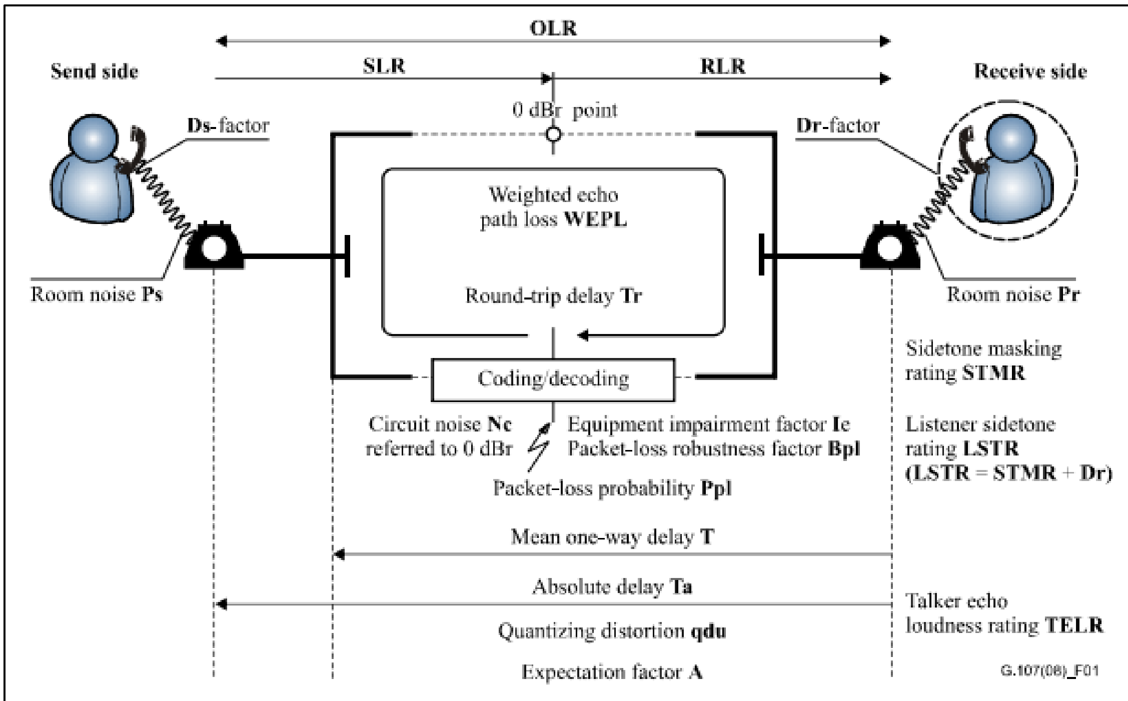

Figure 1 – Reference connection of the E-model

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

7.1 Calculation of the transmission rating factor, R

According to the equipment impairment factor method, the fundamental principle of the E-model is based on a concept given in the description of the OPINE model, see [b-ITU-T P-Sup.3].

Psychological factors on the psychological scale are additive.

The result of any calculation with the E-model in a first step is a transmission rating factor *R*, which combines all transmission parameters relevant for the considered connection. This rating factor *R* is composed of:

$$R = Ro - Is - Id - Ie\text{-}eff + A \quad (7\text{-}1)$$

Ro represents in principle the basic signal-to-noise ratio, including noise sources such as circuit noise and room noise. Factor *Is* is a combination of all impairments which occur more or less simultaneously with the voice signal. Factor *Id* represents the impairments caused by delay and the effective equipment impairment factor *Ie-eff* represents impairments caused by low bit-rate codecs. It also includes impairment due to randomly distributed packet losses. The advantage factor *A* allows for compensation of impairment factors when the user benefits from other types of access to the user. The term *Ro* and the *Is* and *Id* values are subdivided into further specific impairment values. The following clauses give the equations used in the E-model.

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

Table B.1 – Provisional guide for the relation between *R*-value and user satisfaction

R-value (lower limit)	MOS_{CQE} (lower limit)	GoB (%) (lower limit)	PoW (%) (upper limit)	User satisfaction
90	4.34	97	~0	Very satisfied
80	4.03	89	~0	Satisfied
70	3.60	73	6	Some users dissatisfied
60	3.10	50	17	Many users dissatisfied
50	2.58	27	38	Nearly all users dissatisfied

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

43. The methods practiced by TI's use of the accused products include obtaining a first quality index pertaining to the first communications service. For example, the accused products are used by TI to implement the ITU-T G.107 Recommendation. The E-model includes a reference table with different R value and MOS value thresholds, and corresponding perceived

voice quality. Further, the E-model is modelled using large number of subjective tests. Thus, the thresholds of MOS value are based on an aggregate of multiple subjective calls' data. For instance, a MOS value ("first quality index") threshold of 4.34 for best quality is based on an aggregate of data for multiple high quality voice calls using a first communication service.

The E-model (**ITU-T Rec. G.107** [1]) is a transmission planning tool that provides a prediction of the expected voice quality, as perceived by a typical telephone user, for a complete end-to-end (i.e. mouth-to-ear) telephone connection under conversational conditions. The E-model takes into account a wide range of telephony-band impairments, in particular the impairment due to low bit-rate coding devices and one-way delay, as well as the "classical" telephony impairments of loss, noise and echo. It can be applied to assess the voice quality of wireline and wireless scenarios, based on circuit-switched and packet-switched technology.

The E-model is based on modeling the results from a large number of subjective tests done in the past on a wide range of transmission parameters. The primary output of the E-model calculations is a scalar quality rating value known as the "Transmission Rating Factor, R". R can be transformed into other quality measures such as Mean Opinion Score (MOS-CQE [2]), Percentage Good or Better ((GoB) or Percentage Poor or Worse ((PoW). However, caution should be exercised when comparing these transformed measures with values of MOS, %GoB or %PoW from other sources, which may not have been obtained under comparable conditions.

(Source: https://www.itu.int/ITU-T/studygroups/com12/emodelv1/tut.htm)

An estimated mean opinion score (MOS_{CQE}) for the conversational situation in the scale 1-5 can be obtained from the *R*-factor using the equations:

For $R < 0$: $MOS_{CQE} = 1$

For $0 < R < 100$: $MOS_{CQE} = 1 + 0.035R + R(R-60)(100-R)7\cdot 10^{-6}$ (B-4)

For $R > 100$: $MOS_{CQE} = 4.5$

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(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

Table 1 - Definition of categories of speech transmission quality

Range of E-model Rating R	Speech transmission quality category	User satisfaction
90 ≤ R < 100	Best	Very satisfied
80 ≤ R < 90	High	Satisfied
70 ≤ R < 80	Medium	Some users dissatisfied
60 ≤ R < 70	Low	Many users dissatisfied
50 ≤ R < 60	Poor	Nearly all users dissatisfied

NOTE 1 – Connections with E-model Ratings R below 50 are not recommended.
NOTE 2 – Although the trend in transmission planning is to use E-model Ratings R, equations to convert E-model Ratings R into other metrics, e.g. %MOS, %GoB, PoW can be found in **ITU-T Rec. G.107 Annex B** [1].

(Source: https://www.itu.int/ITU-T/studygroups/com12/emodelv1/tut.htm)

44. The methods practiced by TI's use of the accused products include obtaining a second quality index pertaining to the second communications service. For example, the accused products are used by TI to implement the ITU-T G.107 Recommendation. The E-model is applied to a real-time voice call made using a system including an accused product ("second communication service") for measuring its voice quality by calculating the R value and its corresponding MOS value ("second quality index").

7.1 Calculation of the transmission rating factor, R

According to the equipment impairment factor method, the fundamental principle of the E-model is based on a concept given in the description of the OPINE model, see [b-ITU-T P-Sup.3].

Psychological factors on the psychological scale are additive.

The result of any calculation with the E-model in a first step is a transmission rating factor *R*, which combines all transmission parameters relevant for the considered connection. This rating factor *R* is composed of:

$$R = Ro - Is - Id - Ie\text{-}eff + A \quad (7\text{-}1)$$

Ro represents in principle the basic signal-to-noise ratio, including noise sources such as circuit noise and room noise. Factor *Is* is a combination of all impairments which occur more or less simultaneously with the voice signal. Factor *Id* represents the impairments caused by delay and the effective equipment impairment factor *Ie-eff* represents impairments caused by low bit-rate codecs. It also includes impairment due to randomly distributed packet losses. The advantage factor *A* allows for compensation of impairment factors when the user benefits from other types of access to the user. The term *Ro* and the *Is* and *Id* values are subdivided into further specific impairment values. The following clauses give the equations used in the E-model.

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

An estimated mean opinion score (MOS_{CQE}) for the conversational situation in the scale 1-5 can be obtained from the R-factor using the equations:

For $R < 0$: $MOS_{CQE} = 1$

For $0 < R < 100$: $MOS_{CQE} = 1 + 0.035R + R(R-60)(100-R)7 \cdot 10^{-6}$ (B-4)

For $R > 100$: $MOS_{CQE} = 4.5$

(Source: https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-G.107-201402-S!!PDF-E&type=items)

45. The methods practiced by TI's use of the accused products include determining that the second communication service is of unacceptable quality if the second quality index differs from the first quality index service by more than a selected amount. For example, the accused products are used by TI to implement the ITU-T G.107 Recommendation. The calculated MOS value is then compared with the reference table to determine the perceived voice quality. If the R value differs from a R value of 90 by more than 40, then the call is considered to be of unacceptable quality. Similarly, if the calculated MOS value ("second quality index") differs from a MOS value of 4.34 ("first quality index") by more than 1.76, then the call is considered to be of unacceptable quality.

Table B.1 – Provisional guide for the relation between *R*-value and user satisfaction

***R*-value (lower limit)**	**MOS_{CQE} (lower limit)**	**GoB (%) (lower limit)**	**PoW (%) (upper limit)**	**User satisfaction**
90	4.34	97	~0	Very satisfied
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NOTE 1 – Connections with E-model Ratings R below 50 are not recommended.
NOTE 2 – Although the trend in transmission planning is to use E-model Ratings R, equations to convert E-model Ratings R into other metrics, e.g. %MOS, %GoB, PoW can be found in **ITU-T Rec. G.107 Annex B** [1].

(Source: https://www.itu.int/ITU-T/studygroups/com12/emodelv1/tut.htm)

46. Far North Patents only asserts method claims from the '230 Patent.

47. TI has had knowledge of the '230 Patent at least as of the date when it was notified of the filing of this action.

48. Far North Patents has been damaged as a result of the infringing conduct by TI alleged above. Thus, TI is liable to Far North Patents in an amount that adequately compensates it for such infringements, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

49. Far North Patents and/or its predecessors-in-interest have satisfied all statutory obligations required to collect pre-filing damages for the full period allowed by law for infringement of the '230 Patent.

COUNT IV

DIRECT INFRINGEMENT OF U.S. PATENT NO. 8,306,053

50. On November 6, 2012, United States Patent No. 8,306,053 ("the '053 Patent") was duly and legally issued by the United States Patent and Trademark Office for an invention entitled "Methods and Apparatus for Providing Quality-of-Service Guarantees in Computer Networks."

51. Far North Patents is the owner of the '053 Patent, with all substantive rights in and to that patent, including the sole and exclusive right to prosecute this action and enforce the '053 Patent against infringers, and to collect damages for all relevant times.

52. TI made, had made, used, imported, provided, supplied, distributed, sold, and/or offered for sale products and/or systems including, for example, its TI AM654 SoC Gigabit Ethernet Switch and AM654x and AM652x Sitara Processor families of products that include advanced quality of service capabilities (collectively, "accused products").

3.3.4.17. AM65x CPSW2g

The TI AM654 SoC Gigabit Ethernet Switch subsystem (CPSW NUSS) has two ports and provides Ethernet packet communication for the device. It supports MII interfaces the Reduced Gigabit Media Independent Interface (RGMII), Reduced Media Independent Interface (RMII), and the Management Data Input/Output (MDIO) interface for physical layer device (PHY) management.

(Source : http://software-dl.ti.com/processor-sdk-linux/esd/docs/latest/linux/Foundational_Components_Kernel_Drivers.html)

6.4.5.3 CPSW2G

The two-port Gigabit Ethernet MAC (MCU_CPSW0) subsystem provides Ethernet packet communication for the device and is configured in a similar manner as a two-port Ethernet switch. MCU_CPSW0 features the Reduced Gigabit Media Independent Interface (RGMII), Reduced Media Independent Interface (RMII), and the Management Data Input/Output (MDIO) interface for physical layer device (PHY) management.

The MCU_CPSW0 subsystem provides the following features:

- One Ethernet port (port 1) with selectable RGMII and RMII interfaces and an internal Communications Port Programming Interface (CPPI) port (port 0)
- Synchronous 10/100/1000 Mbit operation
- Flexible logical FIFO-based packet buffer structure
- Eight priority level Quality Of Service (QOS) support (802.1p)
- Support for Audio/Video Bridging (P802.1Qav/D6.0)
- Support for IEEE 1588 Clock Synchronization (2008 Annex D, Annex E and Annex F)
  - Timestamp module capable of time stamping external timesync events like Pulse-Per-Second and also generating Pulse-Per-Second outputs
  - CPTS module that supports time stamping for IEEE1588 with support for 4 hardware push events and generation of compare output pulses
- DSCP Priority Mapping (IPv4 and IPv6)
- Energy Efficient Ethernet (EEE) support (802.3az)
- Flow Control (802.3x) Support
- Non Blocking switch fabric
- Time Sensitive Network Support
  - IEEE P902.3br/D2.0 Interspersing Express Traffic
  - IEEE 802.1Qbv/D2.2 Enhancements for Scheduled Traffic

(Source : http://www.ti.com/lit/ds/symlink/am6548.pdf)

TEXAS INSTRUMENTS

AM6548, AM6528, AM6546
AM6526, AM6527

SPRSP08H –NOVEMBER 2017–REVISED JUNE 2019

AM654x, AM652x Sitara™ Processors

(Source : http://www.ti.com/lit/ds/symlink/am6548.pdf)

802.1Qbv – Enhancements for scheduled traffic

Time-aware shaper (TAS) makes switches aware of the cycle time for real-time traffic. A per-egress port scheduler for packets creates a periodic window during which there is no interfering traffic.

TI's TSN implementation for Sitara processors supports TAS. TAS is mostly a hardware feature, with a software stack configuring the hardware shaper in each bridge port and talker.

(Source : http://www.ti.com/lit/wp/spry316a/spry316a.pdf)

AM6548, AM6528, AM6546
AM6526, AM6527

TEXAS INSTRUMENTS

SPRSP08H – NOVEMBER 2017 – REVISED JUNE 2019

www.ti.com

peripherals
- Internal MCSPI connection to the rest of SoC

Security:

- Secure boot supported
  - Hardware-enforced root-of-trust
  - Support to switch root-of-trust via backup key
  - Support for takeover protection, IP protection, and anti-roll back protection
- Cryptographic acceleration supported
  - Session-aware cryptographic engine with ability to auto-switch key-material based on incoming data stream
  - Supports cryptographic cores
    - AES – 128/192/256 bits key sizes
    - 3DES – 56/112/168 bits key sizes
    - MD5, SHA1
    - SHA2 – 224/256/384/512
    - DRBG with true random number generator
    - PKA (public key accelerator) to assist in RSA/ECC processing
  - DMA support
- Debugging security
  - Secure software controlled debug access
  - Security aware debugging

- Ring Accelerator (RA)
- Unified DMA (UDMA)
- Up to 2 Timer Managers (TM) (1024 timers each)

Multimedia:

- Display subsystem
  - Two fully input-mapped overlay managers associated with two display outputs
  - One port MIPI® DPI parallel interface
  - One port OLDI
- PowerVR® SGX544-MP1 3D Graphics Processing Unit (GPU)
- One Camera Serial Interface-2 (MIPI CSI-2)
- One port video capture: BT.656/1120 (no embedded sync)

High-speed interfaces:

- One Gigabit Ethernet (CPSW) interface supporting
  - RMII (10/100) or RGMII (10/100/1000)
  - IEEE1588 (2008 Annex D, Annex E, Annex F) with 802.1AS PTP
  - Audio/video bridging (P802.1Qav/D6.0)
  - Energy-efficient Ethernet (802.3az)
  - Jumbo frames (2024 bytes)
  - Clause 45 MDIO PHY management

(Source : http://www.ti.com/lit/ds/symlink/am6548.pdf)

6.4.5.3 CPSW2G

The two-port Gigabit Ethernet MAC (MCU_CPSW0) subsystem provides Ethernet packet communication for the device and is configured in a similar manner as a two-port Ethernet switch. MCU_CPSW0 features the Reduced Gigabit Media Independent Interface (RGMII), Reduced Media Independent Interface (RMII), and the Management Data Input/Output (MDIO) interface for physical layer device (PHY) management.

The MCU_CPSW0 subsystem provides the following features:

- One Ethernet port (port 1) with selectable RGMII and RMII interfaces and an internal Communications Port Programming Interface (CPPI) port (port 0)
- Synchronous 10/100/1000 Mbit operation
- Flexible logical FIFO-based packet buffer structure
- Eight priority level Quality Of Service (QOS) support (802.1p)
- Support for Audio/Video Bridging (P802.1Qav/D6.0)
- Support for IEEE 1588 Clock Synchronization (2008 Annex D, Annex E and Annex F)
  - Timestamp module capable of time stamping external timesync events like Pulse-Per-Second and also generating Pulse-Per-Second outputs
  - CPTS module that supports time stamping for IEEE1588 with support for 4 hardware push events and generation of compare output pulses
- DSCP Priority Mapping (IPv4 and IPv6)
- Energy Efficient Ethernet (EEE) support (802.3az)
- Flow Control (802.3x) Support
- Non Blocking switch fabric
- Time Sensitive Network Support
  - IEEE P902.3br/D2.0 Interspersing Express Traffic
  - IEEE 802.1Qbv/D2.2 Enhancements for Scheduled Traffic

(Source : http://www.ti.com/lit/ds/symlink/am6548.pdf)

53. By doing so, TI has directly infringed (literally and/or under the doctrine of equivalents) at least Claims 1 and 14 of the '053 Patent. TI's infringement in this regard is ongoing.

54. TI has infringed the '053 Patent by making, having made, using, importing, providing, supplying, distributing, selling or offering for sale products including a device adapter comprising a transmission unit configured to transmit data from a real time device via a network according to a time frame, wherein the time frame is substantially synchronized in the device adapter and at least one other device adapter, the time frame repeating periodically and including a plurality of assigned time phases and a free access phase. For example, the accused products are configured to be used to implement the IEEE 802.1Q standard. IEEE standard 802.1Q implements a method in which a time aware bridged LAN transmits data from one end point i.e,

Precision Time Protocol ("PTP") instance to another. The endpoints transmit data that is a mix of time-critical traffic and other traffic, (i.e, real time data and non-real time data) via PTP instances such as bridges (device adapters). The end point can be either a real time device or a non-real time device. The bridged network uses 802.1AS base time to synchronize all the clocks of ports associated with bridges (device adapters). Using the Best Master Clock Algorithm, the synchronization time signal is transmitted from a grandmaster to other ports. IEEE Std. 802.1AS™-2011 is normative and essential to implement an IEEE Std. 802.1Q Compliant System. IEEE Std. 802.1Q-2018 defines parameters, such as AdminBaseTime and OpenBaseTime, which are used to synchronize the clocks across the network. The bridges containing ports schedule the transmission of traffic based on the synchronized time. Each port associated with a specific set of transmission queues includes a plurality of transmission gates. A transmission gate can be in a closed state or open state. The functionality of assigned time phases is achieved using open gates transmitting data packets during transmission time. The functionality of a free access phase is achieved when the gates are opened for transmission during any time. IEEE Std. 802.1Q-2018 supports cyclic queuing and forwarding structures to create synchronized frames and gates which repeat periodically (Annex T).

1.1 Project Number: P802.1Qbv
1.2 Type of Document: Standard
1.3 Life Cycle: Full Use

2.1 Title: Standard for Local and metropolitan area networks--Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks Amendment: Enhancements for Scheduled Traffic

5.2.b. Scope of the project: This amendment specifies time-aware queue-draining procedures, managed objects and extensions to existing protocols that enable bridges and end stations to schedule the transmission of frames based on a synchronized time. Virtual Local Area Network (VLAN) tag encoded priority values are allocated allowing simultaneous support of scheduled traffic, credit-based shaper traffic and other bridged traffic over Local Area Networks (LANs).

(Source: http://www.ieee802.org/1/files/public/docs2014/bv-p802-1Qbv-par-modification-1114.pdf)

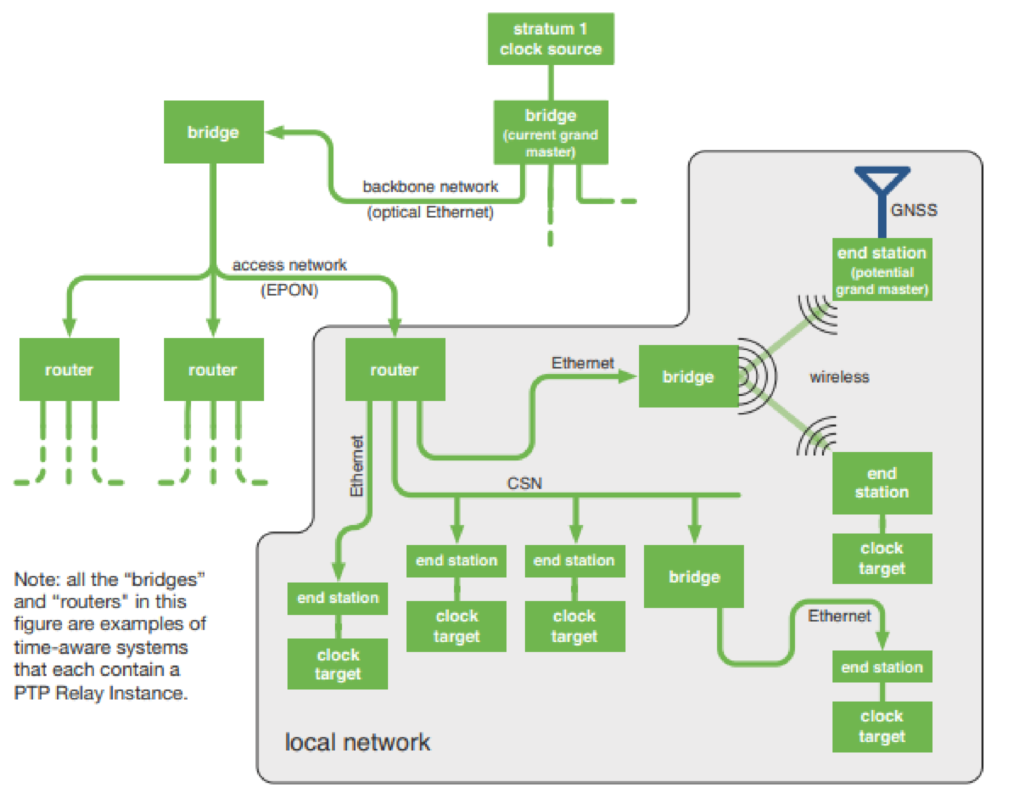

Figure 7-1—Time-aware network example

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

7.2 Architecture of a time-aware network

7.2.1 General

A time-aware network consists of a number of interconnected time-aware systems that support the gPTP defined within this standard. These time-aware systems can be any networking device, including, for example, bridges, routers, and end stations. A set of time-aware systems that are interconnected by gPTP-capable network elements is called a *gPTP network*. Each instance of gPTP that the time-aware systems support is in one *gPTP domain*, and the instances of gPTP are said to be part of that gPTP domain. A time-aware system can support, and therefore be part of, more than one gPTP domain. The entity of a single time-aware system that executes gPTP in one gPTP domain is called a PTP Instance. A time-aware system can contain multiple PTP Instances, which are each associated with a different gPTP domain. There are two

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

3.16 PTP End Instance: A PTP Instance that is capable of acting as the source of synchronized time on the network, or destination of synchronized time using the IEEE 802.1AS protocol, or both.

3.17 PTP Instance: A PTP Relay Instance or a PTP End Instance. A PTP Instance implements those portions of this standard indicated as applicable to a PTP Relay Instance or a PTP End Instance. Each PTP Instance operates in exactly one domain.

3.18 PTP Link: Within a domain, a network segment between two PTP Ports using the peer-to-peer delay mechanism of this standard. The peer-to-peer delay mechanism is designed to measure the propagation time over such a link.

NOTE—A PTP Link between PTP Ports of PTP Instances is also a gPTP Communication Path (see 3.9).

3.19 PTP Relay Instance: A PTP Instance that is capable of communicating synchronized time received on one port to other ports, using the IEEE 802.1AS protocol.

NOTE—A PTP Relay Instance could, for example, be contained in a bridge, a router, or a multi-port end station.

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

Traffic scheduling

This annex provides some background to the mechanisms provided in this standard for traffic scheduling, with the intent of providing some insight into the motivation for the provision of mechanisms for traffic scheduling and some of the ways that the mechanisms might be used.

Q.1 Motivation

Some applications have a need for frame delivery that is highly predictable in terms of the time at which frame transmission will occur, and the overall latency and jitter that will be experienced as the frame is propagated to its destination. Examples include industrial and automotive control applications, where data transmitted over the network is used to feed the parameters of control loops that are critical to the operation of the plant or machinery involved, and where frames carrying control data are transmitted on a repeating time schedule; late delivery of such frames can result in instability, inaccuracy, or failure of the operation of the control loops concerned. In some implementations, this need has been met by the provision of dedicated, highly engineered networks that are used solely for the transmission of time-critical control traffic; however, as the bandwidth occupied by such traffic is often low, and the cost of providing a dedicated control network can be high, it can be desirable to mix time-critical traffic with other classes of traffic in the same network, as long as such mixing can be achieved while still meeting the timing requirements of the time-critical traffic.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

b) gPTP specifies a media-independent sublayer that simplifies the integration within a single timing domain of multiple different networking technologies with radically different media access protocols. gPTP specifies a media-dependent sublayer for each medium. The information exchanged between PTP Instances has been generalized to support different packet formats and management schemes appropriate to the particular networking technology. IEEE Std 1588-2019, on the other

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

7.2.2 Time-aware network consisting of a single gPTP domain

Figure 7-1 illustrates an example time-aware network consisting of a single gPTP domain, using all theabove network technologies (i.e., (c) - (f) of 7.2.1), where end stations on several local networks are connected to a grandmaster on a backbone network via an EPON access network.

Any PTP Instance with clock sourcing capabilities can be a potential grandmaster, so there is a selection method (the *best master clock algorithm*, or BMCA) that ensures that all of the PTP Instances in a gPTP domain use the same grandmaster.[12] The BMCA is largely identical to that used in IEEE Std 1588-2019,

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

10.3.1.1 Best master clock algorithm overview

In the BMCA (i.e., method (a) of 10.3.1), best master selection information is exchanged between PTP Instances of time-aware systems via Announce messages (see 10.5 and 10.6). Each Announce message contains time-synchronization spanning tree vector information that identifies one PTP Instance as the root of the time-synchronization spanning tree and, if the PTP Instance is grandmaster-capable, the grandmaster. Each PTP Instance in turn uses the information contained in the Announce messages it receives, along with its knowledge of itself, to compute which of the PTP Instances that it has knowledge of ought to be the root of the spanning tree and, if grandmaster-capable, the grandmaster. As part of constructing the time-synchronization spanning tree, each port of each PTP Instance is assigned a port state from Table 10-2 by state machines associated with the ports and with the PTP Instance as a whole.

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

c) In gPTP there are only two types of PTP Instances: PTP End Instances and PTP Relay Instances, while IEEE 1588 has ordinary clocks, boundary clocks, end-to-end transparent clocks, and P2P transparent clocks. A PTP End Instance corresponds to an IEEE 1588 ordinary clock, and a PTP Relay Instance is a type of IEEE 1588 boundary clock where its operation is very tightly defined, so much so that a PTP Relay Instance with Ethernet ports can be shown to be mathematically equivalent to a P2P transparent clock in terms of how synchronization is performed, as shown in

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

- **Grand Master selection**
  - GM-capable stations advertise themselves via ANNOUNCE messages
  - If a station hears from station with "better" clock, it does not send ANNOUNCE
    - Configurable "Priority" field can override clock quality
    - MAC address is tie breaker
  - Time relays drop all inferior ANNOUNCE messages
    - Forward only the best
  - Last one standing is Grand Master for the domain
    - GM is the root of the 802.1AS timing tree
    - GM periodically sends the current time

(Source: https://avnu.org/wp-content/uploads/2014/05/as-kbstanton-8021AS-tutorial-0714-v01.pdf)

IEEE Std 802.1Q-2018
IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in the text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI X3.159, American National Standards for Information Systems—Programming Language—C.[5]

IEEE Std 802®, IEEE Standard for Local and metropolitan area networks: Overview and Architecture.[6,7]

IEEE Std 802.1AB™, IEEE Standard for Local and metropolitan area networks—Station and Media Access Control Connectivity Discovery.

IEEE Std 802.1AC™, IEEE Standard for Local and metropolitan area networks—Media Access Control (MAC) Service Definition.

IEEE Std 802.1AE™, IEEE Standard for Local and metropolitan area networks—Media Access Control (MAC) Security.

IEEE Std 802.1AS™, IEEE Standard for Local and metropolitan area networks—Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

8.6.9.4.1 AdminBaseTime

The administrative value of base time, expressed as an IEEE 1588 precision time protocol (PTP) [B24] timescale (see 8.2 of IEEE Std 802.1AS™-2011 [B11]). This value can be changed by management, and is used by the List Config state machine (8.6.9.3) to set the value of OperBaseTime (8.6.9.4.18).

NOTE—Time is expressed in the PTP timescale as the number of seconds, nanoseconds, and fractional nanoseconds that have elapsed since 1 January 1970 00:00:00 TAI.

NOTE 2—If AdminBaseTime is set to the same time in the past in all bridges and end stations, OperBaseTime is always in the past, and all cycles start synchronized. Using AdminBaseTime in the past is appropriate when you can start schedules prior to starting the application that uses the schedules. Use of AdminBaseTime in the future is intended to change a currently running schedule in all bridges and end stations to a new schedule at a future time. Using AdminBaseTime in the future is appropriate when schedules must be changed without stopping the application.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

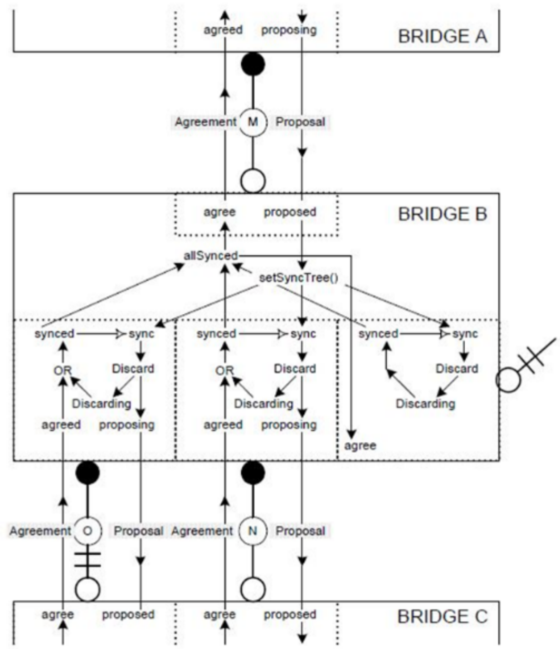

Figure 13-10—Agreements and Proposals

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

NOTE 2—Agreements can be generated without prior receipt of a Proposal as soon as the necessary conditions are met. Subsequent receipt of a Proposal serves to elicit a further Agreement. If all other ports have already been synchronized (allSynced in Figure 13-10) and the Proposal's priority vector does not convey worse information, synchronization is maintained and there is no need to transition Designated Ports to Discarding once more, or to transmit further Proposals.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

8.6.8.4 Enhancements for scheduled traffic

A Bridge or an end station may support enhancements that allow transmission from each queue to be scheduled relative to a known timescale. In order to achieve this, a transmission gate is associated with each queue; the state of the transmission gate determines whether or not queued frames can be selected for transmission (see Figure 8-12). For a given queue, the transmission gate can be in one of two states:

a) *Open*: Queued frames are selected for transmission, in accordance with the definition of the transmission selection algorithm associated with the queue.
b) *Closed*: Queued frames are not selected for transmission.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

8.6.8 Transmission selection

For each Port, frames are selected for transmission on the basis of the traffic classes that the Port supports and the operation of the transmission selection algorithms supported by the corresponding queues on that Port. For a given Port and traffic class, frames are selected from the corresponding queue for transmission if and only if

a) The operation of the transmission selection algorithm supported by that queue determines that there is a frame available for transmission; and

b) For each queue corresponding to a numerically higher value of traffic class supported by the Port, the operation of the transmission selection algorithm supported by that queue determines that there is no frame available for transmission.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

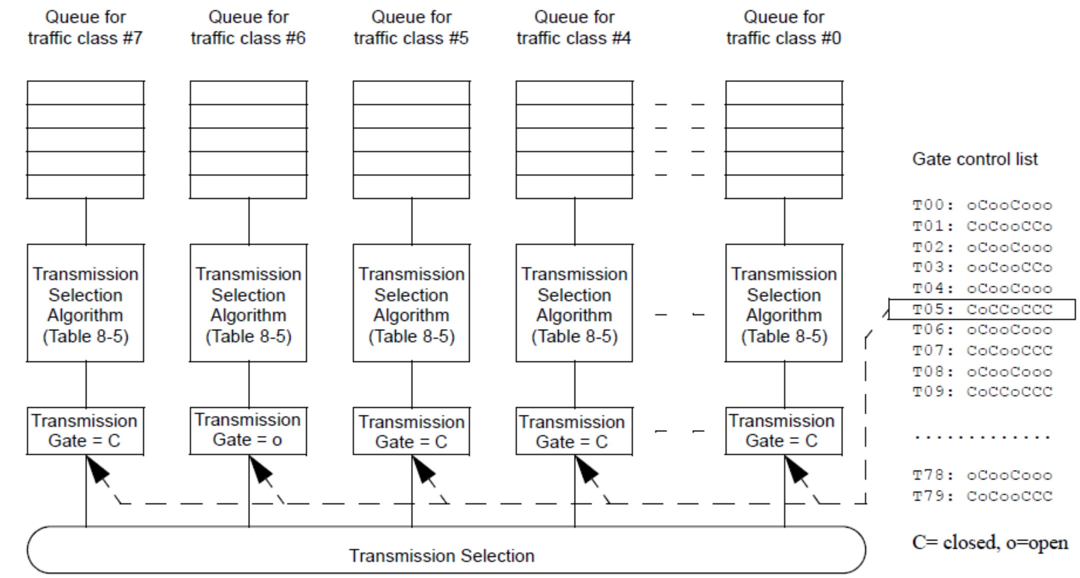

Figure 8-12—Transmission selection with gates

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

> A *gate control list* associated with each Port contains an ordered list of gate operations. Each gate operation changes the transmission gate state for the gate associated with each of the Port's traffic class queues. In an implementation that does not support enhancements for scheduled traffic, all gates are assumed to be permanently in the *open* state. Table 8-6 identifies the gate operation types, their parameters, and the actions that result from their execution. The state machines that control the execution of the gate control list, along with their variables and procedures, are specified in 8.6.9.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015)).

> **3.3 gating cycle:** The period of time over which the sequence of operations in a gate control list repeats.
>
> **3.4 transmission gate:** A gate that connects or disconnects the transmission selection function of the forwarding process from the queue, allowing or preventing it from selecting frames from that queue. The gate has two states, Open and Closed.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

Cyclic queuing and forwarding[53]

T.1 Overview of CQF

Cyclic queuing and forwarding (CQF) is a method of traffic shaping that can deliver deterministic, and easily calculated, latency for time-sensitive traffic streams. As the name implies, the principle underlying CQF is that stream traffic is transmitted and queued for transmission along a network path in a cyclic manner. Time is divided into numbered time intervals i, $i+1$, $i+2$, ... $i+N$, each of duration d. Frames transmitted by a Bridge, *Alice*, during time interval i are received by a downstream Bridge, *Bob*, during time interval i and are transmitted onwards by *Bob* towards Bridge *Charlie* during time interval $i+1$, and so on. A starting assumption is that, for a given traffic class, all Bridges and all end stations connected to a given bridge have a common understanding (to a known accuracy) of the start time of cycle i, and the cycle duration, d.

Frames transmitted by *Alice* during interval i are transmitted by *Bob* in interval $i+1$; the maximum possible delay experienced by a given frame is from the beginning of i to the end of $i+1$, or twice d. Similarly, the minimum possible delay experienced is from the end of i to the beginning of $i+1$, which is zero. More generally, the maximum delay experienced by a given frame is

$$(h+1) \times d$$

and the minimum delay experienced by a given frame is

$$(h-1) \times d$$

where h is the number of hops.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

55. The accused products include a device adapter that is configured to transmit data during at least one of an assigned time phase associated with the device adapter prior to transmission of data from the real-time device by the device adapter, and included in the plurality of assigned time phases, or the free access phase, to refrain from transmitting data during time phases of the plurality of assigned time phases that are not associated with the device adapter, and to be able to determine whether to defer transmission of data during the assigned time phase associated with the device adapter and the free access phase to allow a non-real time device to transmit data. For example, the accused products are configured to be used to implement the IEEE 802.1Q standard. IEEE standard 802.1Q shows that scheduling of ports' transmission gates (configured) for transmission of data starts prior to the transmission of real-time data. The

functionality of assigned time phases is achieved using open gates transmitting data packets during scheduled transmission time. Per Clause 8.6.8 of the IEEE Std. 802.1Q, each time phase is assigned to a specific device adapter prior to transmission of real-time data by the specific device adapter. Furthermore, IEEE 802.1Q performs traffic shaping through Per-Stream Filtering and Policing (PSTP). IEEE standard 802.1Q implements a method in which open gates transmit data packets during transmission time and closed gates refrain data packets from transmission. The functionality of assigned time phases is achieved using open gates transmitting data packets during transmission time. The functionality of free access phase is achieved by the gates that are opened for transmission during any time. IEEE Std. 802.1Q supports Forwarding and Queuing Enhancements for Time Sensitive Streams. Thus, one of the plurality of device adaptors is configured to transmit data during at least one of a respective assigned time phase or free access phase, to refrain from transmitting data during time phases not assigned to the respective one of the plurality of device adapters. IEEE Std. 802.1Q provides traffic shaping for various classes of data transmission and determining whether to defer transmission of data during at least one of the assigned time phase or the free access phase to allow a non-real time device to transmit data.

NOTE 2—If AdminBaseTime is set to the same time in the past in all bridges and end stations, OperBaseTime is always in the past, and all cycles start synchronized. Using AdminBaseTime in the past is appropriate when you can start schedules prior to starting the application that uses the schedules. Use of AdminBaseTime in the future is intended to

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

1.1 Project Number: P802.1Qbv
1.2 Type of Document: Standard
1.3 Life Cycle: Full Use

5.5 Need for the Project: The credit-based shaper works well in arbitrary networks (i.e., non-engineered). Networks employing scheduled transmissions are able to control real-time processes. This amendment enables those two kinds of networks to be consolidated into a single network, with a significant cost reduction to the user.

(Source: http://www.ieee802.org/1/files/public/docs2014/bv-p802-1Qbv-par-modification-1114.pdf)

8.6.8 Transmission selection

For each Port, frames are selected for transmission on the basis of the traffic classes that the Port supports and the operation of the transmission selection algorithms supported by the corresponding queues on that Port. For a given Port and traffic class, frames are selected from the corresponding queue for transmission if and only if

a) The operation of the transmission selection algorithm supported by that queue determines that there is a frame available for transmission; and

b) For each queue corresponding to a numerically higher value of traffic class supported by the Port, the operation of the transmission selection algorithm supported by that queue determines that there is no frame available for transmission.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

5.4.1.9 Cyclic queuing and forwarding (CQF) requirements

A VLAN Bridge component implementation that conforms to the provisions of this standard for CQF (see Annex T) shall

a) Support the enhancements for scheduled traffic as specified in 8.6.8.4.

b) Support the state machines for scheduled traffic as specified in 8.6.9.
c) Support the state machines for stream gate control as specified in 8.6.10.
d) Support the management entities for scheduled traffic as specified in 12.29.
e) Support the requirements for per-stream filtering and policing (PSFP) as stated in 5.4.1.8.
f) Support the management entities for PSFP as specified in 12.31.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

5.4.1.5 Forwarding and Queuing Enhancements for time-sensitive streams (FQTSS)—requirements

A VLAN Bridge component implementation that conforms to the provisions of this standard for FQTSS shall

a) Support a minimum of two traffic classes on all Ports, of which
   1) A minimum of one traffic class supports the strict priority algorithm for transmission selection (8.6.8.1), and
   2) One traffic class is a stream reservation (SR) class.
b) Support the operation of the credit-based shaper algorithm (8.6.8.2) on all Ports as the transmission selection algorithm used for the SR class.
c) Support SRP domain boundary port priority regeneration override as defined in 6.9.4, and the default priority regeneration override value defined in Table 6-5, for SR class "B."
d) Support the tables and procedures for mapping priorities to traffic classes as defined in 34.5.

SR: Stream Reservation, SRP: Stream Reservation Protocol

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

8.6.8.4 Enhancements for scheduled traffic

A Bridge or an end station may support enhancements that allow transmission from each queue to be scheduled relative to a known timescale. In order to achieve this, a transmission gate is associated with each queue; the state of the transmission gate determines whether or not queued frames can be selected for transmission (see Figure 8-12). For a given queue, the transmission gate can be in one of two states:

a) *Open*: Queued frames are selected for transmission, in accordance with the definition of the transmission selection algorithm associated with the queue.
b) *Closed*: Queued frames are not selected for transmission.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

A *gate control list* associated with each Port contains an ordered list of gate operations. Each gate operation changes the transmission gate state for the gate associated with each of the Port's traffic class queues. In an implementation that does not support enhancements for scheduled traffic, all gates are assumed to be permanently in the *open* state. Table 8-6 identifies the gate operation types, their parameters, and the actions that result from their execution. The state machines that control the execution of the gate control list, along with their variables and procedures, are specified in 8.6.9.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

5.4.1.5 Forwarding and Queuing Enhancements for time-sensitive streams (FQTSS)—requirements

A VLAN Bridge component implementation that conforms to the provisions of this standard for FQTSS shall

a) Support a minimum of two traffic classes on all Ports, of which
   1) A minimum of one traffic class supports the strict priority algorithm for transmission selection (8.6.8.1), and
   2) One traffic class is a stream reservation (SR) class.
b) Support the operation of the credit-based shaper algorithm (8.6.8.2) on all Ports as the transmission selection algorithm used for the SR class.
c) Support SRP domain boundary port priority regeneration override as defined in 6.9.4, and the default priority regeneration override value defined in Table 6-5, for SR class "B."
d) Support the tables and procedures for mapping priorities to traffic classes as defined in 34.5.

SR: Stream Reservation, SRP: Stream Reservation Protocol

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

5.4.1.6 ETS Bridge requirements

A device supporting ETS shall

a) Support at least 3 traffic classes (37.3).

NOTE—A minimum of 3 traffic classes allows a minimum configuration such that one traffic class contains priorities with PFC enabled, one traffic class contains priorities with PFC disabled, and one traffic class using strict priority.

b) Support bandwidth configuration with a granularity of 1% or finer (37.3).
c) Support bandwidth allocation with a precision of 10% (37.3).
d) Support a transmission selection policy such that if one of the traffic classes does not consume its allocated bandwidth, then any unused bandwidth is available to other traffic classes (37.3).
e) Support DCBX (Clause 38).

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

56. TI has infringed the '053 Patent by using the accused products and thereby practicing a method that includes transmitting a synchronization signal at regular intervals to synchronize local clocks of each of a plurality of device adapters. For example, the accused products are used by TI to implement the IEEE 802.1Q standard. IEEE standard 802.1Q implements a method in which a time aware bridged LAN use 802.1AS base time to synchronize

all the clocks of ports associated with bridges (device adapters) by periodically (regular intervals) sending the Announce messages. Using Best Master Clock Algorithm, the synchronization time signal is transmitted from a grandmaster to other ports via periodic Announce messages. IEEE Std. 802.1AS™-2011 is normative and essential to implement an IEEE Std. 802.1Q Compliant System. IEEE Std. 802.1Q-2018 defines parameters, such as AdminBaseTime and OpenBaseTime, which are used to synchronize the clocks across the network.

1.1 Project Number: P802.1Qbv
1.2 Type of Document: Standard
1.3 Life Cycle: Full Use

2.1 Title: Standard for Local and metropolitan area networks--Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks Amendment: Enhancements for Scheduled Traffic

5.2.b. Scope of the project: This amendment specifies time-aware queue-draining procedures, managed objects and extensions to existing protocols that enable bridges and end stations to schedule the transmission of frames based on a synchronized time. Virtual Local Area Network (VLAN) tag encoded priority values are allocated allowing simultaneous support of scheduled traffic, credit-based shaper traffic and other bridged traffic over Local Area Networks (LANs).

(Source: http://www.ieee802.org/1/files/public/docs2014/bv-p802-1Qbv-par-modification-1114.pdf)

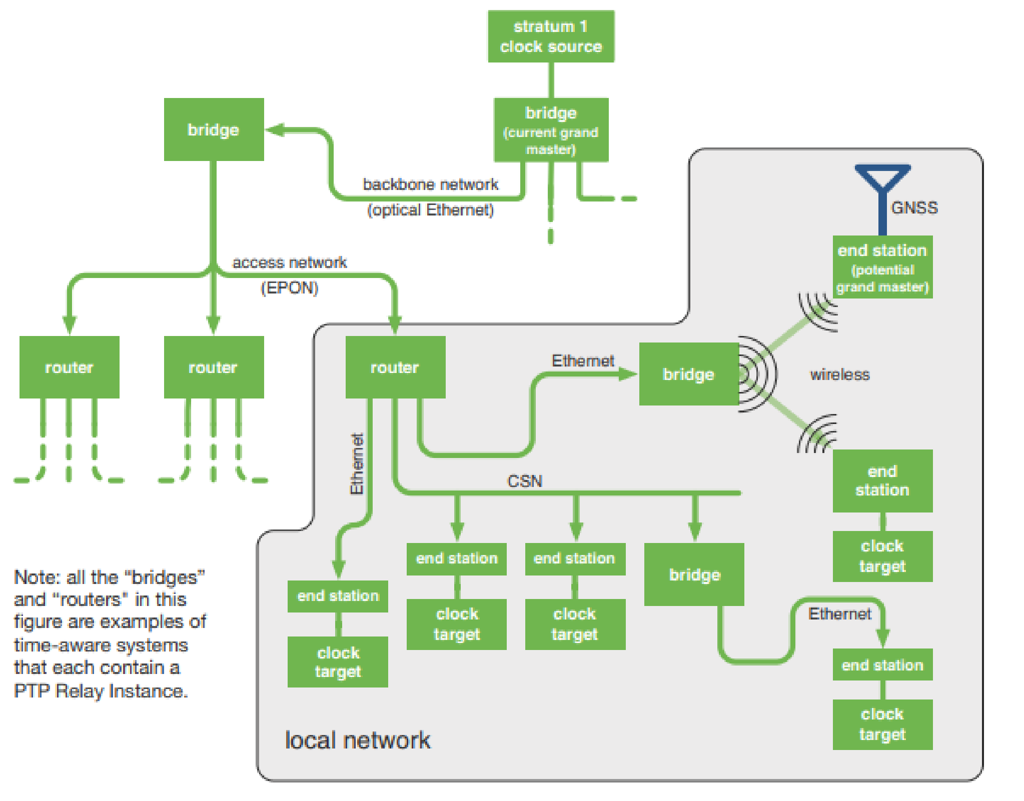

Figure 7-1—Time-aware network example

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

7.2 Architecture of a time-aware network

7.2.1 General

A time-aware network consists of a number of interconnected time-aware systems that support the gPTP defined within this standard. These time-aware systems can be any networking device, including, for example, bridges, routers, and end stations. A set of time-aware systems that are interconnected by gPTP-capable network elements is called a *gPTP network*. Each instance of gPTP that the time-aware systems support is in one *gPTP domain*, and the instances of gPTP are said to be part of that gPTP domain. A time-aware system can support, and therefore be part of, more than one gPTP domain. The entity of a single time-aware system that executes gPTP in one gPTP domain is called a PTP Instance. A time-aware system can contain multiple PTP Instances, which are each associated with a different gPTP domain. There are two

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

3.16 PTP End Instance: A PTP Instance that is capable of acting as the source of synchronized time on the network, or destination of synchronized time using the IEEE 802.1AS protocol, or both.

3.17 PTP Instance: A PTP Relay Instance or a PTP End Instance. A PTP Instance implements those portions of this standard indicated as applicable to a PTP Relay Instance or a PTP End Instance. Each PTP Instance operates in exactly one domain.

3.18 PTP Link: Within a domain, a network segment between two PTP Ports using the peer-to-peer delay mechanism of this standard. The peer-to-peer delay mechanism is designed to measure the propagation time over such a link.

NOTE—A PTP Link between PTP Ports of PTP Instances is also a gPTP Communication Path (see 3.9).

3.19 PTP Relay Instance: A PTP Instance that is capable of communicating synchronized time received on one port to other ports, using the IEEE 802.1AS protocol.

NOTE—A PTP Relay Instance could, for example, be contained in a bridge, a router, or a multi-port end station.

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

7.2.2 Time-aware network consisting of a single gPTP domain

Figure 7-1 illustrates an example time-aware network consisting of a single gPTP domain, using all theabove network technologies (i.e., (c) - (f) of 7.2.1), where end stations on several local networks are connected to a grandmaster on a backbone network via an EPON access network.

Any PTP Instance with clock sourcing capabilities can be a potential grandmaster, so there is a selection method (the *best master clock algorithm*, or BMCA) that ensures that all of the PTP Instances in a gPTP domain use the same grandmaster.[12] The BMCA is largely identical to that used in IEEE Std 1588-2019,

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

10.3.1.1 Best master clock algorithm overview

In the BMCA (i.e., method (a) of 10.3.1), best master selection information is exchanged between PTP Instances of time-aware systems via Announce messages (see 10.5 and 10.6). Each Announce message contains time-synchronization spanning tree vector information that identifies one PTP Instance as the root of the time-synchronization spanning tree and, if the PTP Instance is grandmaster-capable, the grandmaster. Each PTP Instance in turn uses the information contained in the Announce messages it receives, along with its knowledge of itself, to compute which of the PTP Instances that it has knowledge of ought to be the root of the spanning tree and, if grandmaster-capable, the grandmaster. As part of constructing the time-synchronization spanning tree, each port of each PTP Instance is assigned a port state from Table 10-2 by state machines associated with the ports and with the PTP Instance as a whole.

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

c) In gPTP there are only two types of PTP Instances: PTP End Instances and PTP Relay Instances, while IEEE 1588 has ordinary clocks, boundary clocks, end-to-end transparent clocks, and P2P transparent clocks. A PTP End Instance corresponds to an IEEE 1588 ordinary clock, and a PTP Relay Instance is a type of IEEE 1588 boundary clock where its operation is very tightly defined, so much so that a PTP Relay Instance with Ethernet ports can be shown to be mathematically equivalent to a P2P transparent clock in terms of how synchronization is performed, as shown in

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

- **Grand Master selection**
  - GM-capable stations advertise themselves via ANNOUNCE messages
  - If a station hears from station with "better" clock, it does not send ANNOUNCE
    - Configurable "Priority" field can override clock quality
    - MAC address is tie breaker
  - Time relays drop all inferior ANNOUNCE messages
    - Forward only the best
  - Last one standing is Grand Master for the domain
    - GM is the root of the 802.1AS timing tree
    - GM periodically sends the current time

(Source: https://avnu.org/wp-content/uploads/2014/05/as-kbstanton-8021AS-tutorial-0714-v01.pdf)

IEEE Std 802.1Q-2018
IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in the text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI X3.159, American National Standards for Information Systems—Programming Language—C.[5]

IEEE Std 802®, IEEE Standard for Local and metropolitan area networks: Overview and Architecture.[6,7]

IEEE Std 802.1AB™, IEEE Standard for Local and metropolitan area networks—Station and Media Access Control Connectivity Discovery.

IEEE Std 802.1AC™, IEEE Standard for Local and metropolitan area networks—Media Access Control (MAC) Service Definition.

IEEE Std 802.1AE™, IEEE Standard for Local and metropolitan area networks—Media Access Control (MAC) Security.

IEEE Std 802.1AS™, IEEE Standard for Local and metropolitan area networks—Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

8.6.9.4.1 AdminBaseTime

The administrative value of base time, expressed as an IEEE 1588 precision time protocol (PTP) [B24] timescale (see 8.2 of IEEE Std 802.1AS™-2011 [B11]). This value can be changed by management, and is used by the List Config state machine (8.6.9.3) to set the value of OperBaseTime (8.6.9.4.18).

NOTE—Time is expressed in the PTP timescale as the number of seconds, nanoseconds, and fractional nanoseconds that have elapsed since 1 January 1970 00:00:00 TAI.

NOTE 2—If AdminBaseTime is set to the same time in the past in all bridges and end stations, OperBaseTime is always in the past, and all cycles start synchronized. Using AdminBaseTime in the past is appropriate when you can start schedules prior to starting the application that uses the schedules. Use of AdminBaseTime in the future is intended to change a currently running schedule in all bridges and end stations to a new schedule at a future time. Using AdminBaseTime in the future is appropriate when schedules must be changed without stopping the application.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

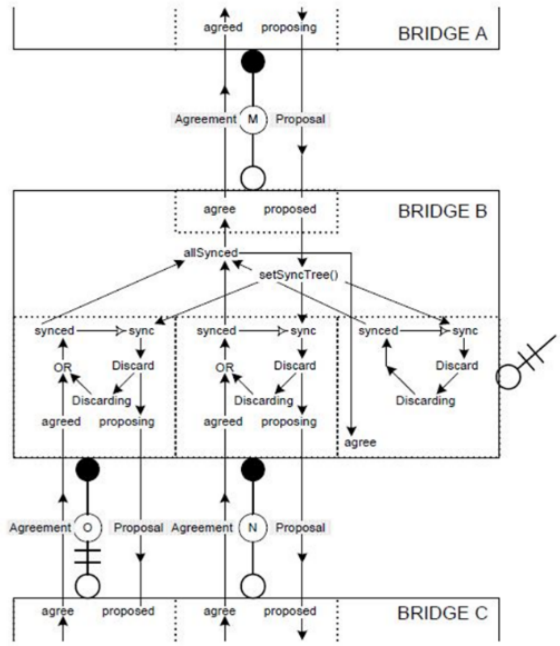

Figure 13-10—Agreements and Proposals

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

> NOTE 2—Agreements can be generated without prior receipt of a Proposal as soon as the necessary conditions are met. Subsequent receipt of a Proposal serves to elicit a further Agreement. If all other ports have already been synchronized (allSynced in Figure 13-10) and the Proposal's priority vector does not convey worse information, synchronization is maintained and there is no need to transition Designated Ports to Discarding once more, or to transmit further Proposals.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

57. The methods practiced by TI's use of the accused products include maintaining a substantially synchronized time frame among the plurality of device adapters interconnected by a network, the time frame repeating periodically and including a plurality of assigned time phases

and a free access phase. For example, the accused products are used by TI to implement the IEEE 802.1Q standard. The time aware bridged LAN uses 802.1AS base time to maintain synchronized time for all the ports in the bridges (device adapters). The bridges containing ports schedule the transmission of traffic based on the synchronized time. Each port associated with a specific set of transmission queues includes a plurality of transmission gates. A transmission gate can be in a closed state or open state. The functionality of assigned time phases is achieved using open gates transmitting data packets during transmission time. The functionality of free access phase is achieved when the gates are opened for transmission during any time. IEEE Std. 802.1Q-2018 supports cyclic queuing and forwarding structures to create synchronized frames and gates which repeat periodically (Annex T).

1.1 Project Number: P802.1Qbv
1.2 Type of Document: Standard
1.3 Life Cycle: Full Use

2.1 Title: Standard for Local and metropolitan area networks--Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks Amendment: Enhancements for Scheduled Traffic

5.2.b. Scope of the project: This amendment specifies time-aware queue-draining procedures, managed objects and extensions to existing protocols that enable bridges and end stations to schedule the transmission of frames based on a synchronized time. Virtual Local Area Network (VLAN) tag encoded priority values are allocated allowing simultaneous support of scheduled traffic, credit-based shaper traffic and other bridged traffic over Local Area Networks (LANs).

(Source: http://www.ieee802.org/1/files/public/docs2014/bv-p802-1Qbv-par-modification-1114.pdf)

- **Grand Master selection**
  - GM-capable stations advertise themselves via ANNOUNCE messages
  - If a station hears from station with "better" clock, it does not send ANNOUNCE
    - Configurable "Priority" field can override clock quality
    - MAC address is tie breaker
  - Time relays drop all inferior ANNOUNCE messages
    - Forward only the best
  - Last one standing is Grand Master for the domain
    - GM is the root of the 802.1AS timing tree
    - GM periodically sends the current time

(Source: https://avnu.org/wp-content/uploads/2014/05/as-kbstanton-8021AS-tutorial-0714-v01.pdf)

3.16 PTP End Instance: A PTP Instance that is capable of acting as the source of synchronized time on the network, or destination of synchronized time using the IEEE 802.1AS protocol, or both.

3.17 PTP Instance: A PTP Relay Instance or a PTP End Instance. A PTP Instance implements those portions of this standard indicated as applicable to a PTP Relay Instance or a PTP End Instance. Each PTP Instance operates in exactly one domain.

3.18 PTP Link: Within a domain, a network segment between two PTP Ports using the peer-to-peer delay mechanism of this standard. The peer-to-peer delay mechanism is designed to measure the propagation time over such a link.

NOTE—A PTP Link between PTP Ports of PTP Instances is also a gPTP Communication Path (see 3.9).

3.19 PTP Relay Instance: A PTP Instance that is capable of communicating synchronized time received on one port to other ports, using the IEEE 802.1AS protocol.

NOTE—A PTP Relay Instance could, for example, be contained in a bridge, a router, or a multi-port end station.

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

8.6.8.4 Enhancements for scheduled traffic

A Bridge or an end station may support enhancements that allow transmission from each queue to be scheduled relative to a known timescale. In order to achieve this, a transmission gate is associated with each queue; the state of the transmission gate determines whether or not queued frames can be selected for transmission (see Figure 8-12). For a given queue, the transmission gate can be in one of two states:

a) *Open*: Queued frames are selected for transmission, in accordance with the definition of the transmission selection algorithm associated with the queue.
b) *Closed*: Queued frames are not selected for transmission.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

8.6.8 Transmission selection

For each Port, frames are selected for transmission on the basis of the traffic classes that the Port supports and the operation of the transmission selection algorithms supported by the corresponding queues on that Port. For a given Port and traffic class, frames are selected from the corresponding queue for transmission if and only if

a) The operation of the transmission selection algorithm supported by that queue determines that there is a frame available for transmission; and

b) For each queue corresponding to a numerically higher value of traffic class supported by the Port, the operation of the transmission selection algorithm supported by that queue determines that there is no frame available for transmission.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

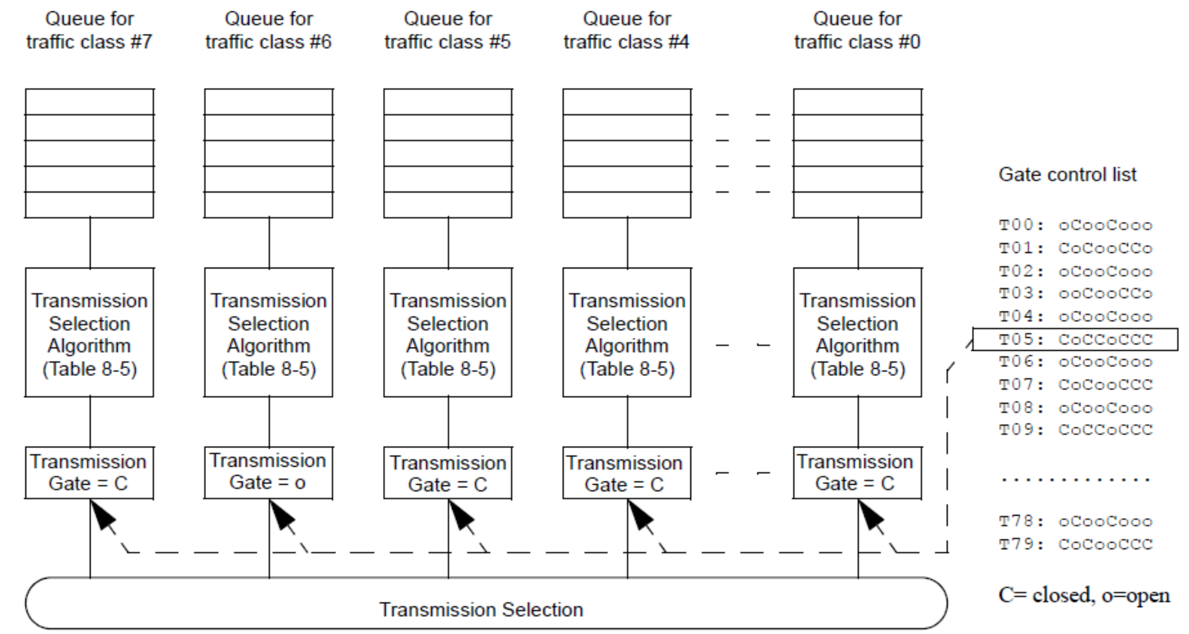

Figure 8-12—Transmission selection with gates

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

A *gate control list* associated with each Port contains an ordered list of gate operations. Each gate operation changes the transmission gate state for the gate associated with each of the Port's traffic class queues. In an implementation that does not support enhancements for scheduled traffic, all gates are assumed to be permanently in the *open* state. Table 8-6 identifies the gate operation types, their parameters, and the actions that result from their execution. The state machines that control the execution of the gate control list, along with their variables and procedures, are specified in 8.6.9.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

3.3 gating cycle: The period of time over which the sequence of operations in a gate control list repeats.

3.4 transmission gate: A gate that connects or disconnects the transmission selection function of the forwarding process from the queue, allowing or preventing it from selecting frames from that queue. The gate has two states, Open and Closed.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

Cyclic queuing and forwarding[53]

T.1 Overview of CQF

Cyclic queuing and forwarding (CQF) is a method of traffic shaping that can deliver deterministic, and easily calculated, latency for time-sensitive traffic streams. As the name implies, the principle underlying CQF is that stream traffic is transmitted and queued for transmission along a network path in a cyclic manner. Time is divided into numbered time intervals *i*, *i*+1, *i*+2, ... *i*+*N*, each of duration *d*. Frames transmitted by a Bridge, *Alice*, during time interval *i* are received by a downstream Bridge, *Bob*, during time interval *i* and are transmitted onwards by *Bob* towards Bridge *Charlie* during time interval *i*+1, and so on. A starting assumption is that, for a given traffic class, all Bridges and all end stations connected to a given bridge have a common understanding (to a known accuracy) of the start time of cycle *i*, and the cycle duration, *d*.

Frames transmitted by *Alice* during interval *i* are transmitted by *Bob* in interval *i*+1; the maximum possible delay experienced by a given frame is from the beginning of *i* to the end of *i*+1, or twice *d*. Similarly, the minimum possible delay experienced is from the end of *i* to the beginning of *i*+1, which is zero. More generally, the maximum delay experienced by a given frame is

$$(h+1) \times d$$

and the minimum delay experienced by a given frame is

$$(h-1) \times d$$

where *h* is the number of hops.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

58. The methods practiced by TI's use of the accused products include assigning each time phase to a specific device adapter prior to transmission of real-time data by the specific device adapter. For example, the accused products are used by TI to implement the IEEE 802.1Q standard. IEEE standard 802.1Q shows that scheduling (assigning) of transmission gates starts prior to the transmission of real-time data. Per clause 8.6.8 of the IEEE Std. 802.1Q, each time phase is assigned to a specific device adapter prior to transmission of real-time data by the specific device adapter. IEEE 802.1Q performs traffic shaping through Per-Stream Filtering and Policing (PSTP).

NOTE 2—If AdminBaseTime is set to the same time in the past in all bridges and end stations, OperBaseTime is always in the past, and all cycles start synchronized. Using AdminBaseTime in the past is appropriate when you can start schedules prior to starting the application that uses the schedules. Use of AdminBaseTime in the future is intended to

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

1.1 Project Number: P802.1Qbv
1.2 Type of Document: Standard
1.3 Life Cycle: Full Use

5.5 Need for the Project: The credit-based shaper works well in arbitrary networks (i.e., non-engineered). Networks employing scheduled transmissions are able to control real-time processes. This amendment enables those two kinds of networks to be consolidated into a single network, with a significant cost reduction to the user.

(Source: http://www.ieee802.org/1/files/public/docs2014/bv-p802-1Qbv-par-modification-1114.pdf)

8.6.8 Transmission selection

For each Port, frames are selected for transmission on the basis of the traffic classes that the Port supports and the operation of the transmission selection algorithms supported by the corresponding queues on that Port. For a given Port and traffic class, frames are selected from the corresponding queue for transmission if and only if

a) The operation of the transmission selection algorithm supported by that queue determines that there is a frame available for transmission; and

b) For each queue corresponding to a numerically higher value of traffic class supported by the Port, the operation of the transmission selection algorithm supported by that queue determines that there is no frame available for transmission.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

5.4.1.9 Cyclic queuing and forwarding (CQF) requirements

A VLAN Bridge component implementation that conforms to the provisions of this standard for CQF (see Annex T) shall

a) Support the enhancements for scheduled traffic as specified in 8.6.8.4.

b) Support the state machines for scheduled traffic as specified in 8.6.9.
c) Support the state machines for stream gate control as specified in 8.6.10.
d) Support the management entities for scheduled traffic as specified in 12.29.
e) Support the requirements for per-stream filtering and policing (PSFP) as stated in 5.4.1.8.
f) Support the management entities for PSFP as specified in 12.31.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

5.4.1.5 Forwarding and Queuing Enhancements for time-sensitive streams (FQTSS)—requirements

A VLAN Bridge component implementation that conforms to the provisions of this standard for FQTSS shall

a) Support a minimum of two traffic classes on all Ports, of which
   1) A minimum of one traffic class supports the strict priority algorithm for transmission selection (8.6.8.1), and
   2) One traffic class is a stream reservation (SR) class.
b) Support the operation of the credit-based shaper algorithm (8.6.8.2) on all Ports as the transmission selection algorithm used for the SR class.
c) Support SRP domain boundary port priority regeneration override as defined in 6.9.4, and the default priority regeneration override value defined in Table 6-5, for SR class "B."
d) Support the tables and procedures for mapping priorities to traffic classes as defined in 34.5.

SR: Stream Reservation, SRP: Stream Reservation Protocol

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

59. The plurality of device adaptors recited above in connection with TI's use of the accused products includes a respective one of the plurality of device adapters that is configured to transmit data during at least one of a respective assigned time phase or the free access phase, to refrain from transmitting data during time phases not assigned to the respective one of the plurality of device adapters, and to determine whether to defer transmission of data during at least one of the assigned time phase or the free access phase to allow a non-real time device to transmit data. For example, the accused products are used by TI to implement the IEEE 802.1Q standard. IEEE standard 802.1Q implements a method in which open gates transmit data packets during transmission time and closed gates refrain data packets from transmission. The functionality of assigned time phases is achieved using open gates transmitting data packets during transmission time. The functionality of free access phase is achieved by the gates that are opened for transmission during any time. IEEE Std. 802.1Q supports Forwarding and Queuing Enhancements for Time Sensitive Streams. Thus, one of the plurality of device adaptors is configured to transmit data during at least one of a respective assigned time phase or free access

phase, to refrain from transmitting data during time phases not assigned to the respective one of the plurality of device adapters. IEEE Std. 802.1Q provides traffic shaping for various classes of data transmission and determining whether to defer transmission of data during at least one of the assigned time phase or the free access phase to allow a non-real time device to transmit data.

8.6.8.4 Enhancements for scheduled traffic

A Bridge or an end station may support enhancements that allow transmission from each queue to be scheduled relative to a known timescale. In order to achieve this, a transmission gate is associated with each queue; the state of the transmission gate determines whether or not queued frames can be selected for transmission (see Figure 8-12). For a given queue, the transmission gate can be in one of two states:

a) *Open*: Queued frames are selected for transmission, in accordance with the definition of the transmission selection algorithm associated with the queue.
b) *Closed*: Queued frames are not selected for transmission.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

A *gate control list* associated with each Port contains an ordered list of gate operations. Each gate operation changes the transmission gate state for the gate associated with each of the Port's traffic class queues. In an implementation that does not support enhancements for scheduled traffic, all gates are assumed to be permanently in the *open* state. Table 8-6 identifies the gate operation types, their parameters, and the actions that result from their execution. The state machines that control the execution of the gate control list, along with their variables and procedures, are specified in 8.6.9.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

5.4.1.5 Forwarding and Queuing Enhancements for time-sensitive streams (FQTSS)—requirements

A VLAN Bridge component implementation that conforms to the provisions of this standard for FQTSS shall

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   1) A minimum of one traffic class supports the strict priority algorithm for transmission selection (8.6.8.1), and
   2) One traffic class is a stream reservation (SR) class.
b) Support the operation of the credit-based shaper algorithm (8.6.8.2) on all Ports as the transmission selection algorithm used for the SR class.
c) Support SRP domain boundary port priority regeneration override as defined in 6.9.4, and the default priority regeneration override value defined in Table 6-5, for SR class "B."
d) Support the tables and procedures for mapping priorities to traffic classes as defined in 34.5.

SR: Stream Reservation, SRP: Stream Reservation Protocol

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

5.4.1.6 ETS Bridge requirements

A device supporting ETS shall

a) Support at least 3 traffic classes (37.3).

NOTE—A minimum of 3 traffic classes allows a minimum configuration such that one traffic class contains priorities with PFC enabled, one traffic class contains priorities with PFC disabled, and one traffic class using strict priority.

b) Support bandwidth configuration with a granularity of 1% or finer (37.3).
c) Support bandwidth allocation with a precision of 10% (37.3).
d) Support a transmission selection policy such that if one of the traffic classes does not consume its allocated bandwidth, then any unused bandwidth is available to other traffic classes (37.3).
e) Support DCBX (Clause 38).

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

60. TI has had knowledge of the '053 Patent at least as of its issuance on November 6, 2012. On November 8, 2008, U.S. Patent Application Publication No. 2004/0208158, the publication of the '053 Patent's parent application, was cited by the examiner in an office action during the prosecution of U.S. Patent No. 7,668,243, entitled "Audio and video clock synchronization in a wireless network" and assigned to Texas Instruments Incorporated. That office action identified the Fellman publication as pertinent to the applicant's disclosure, stating that "Fellman et al. (U.S. Patent Application Publication no. 2004/0208158 A1) teaches method and apparatus for providing quality-of-service guarantees in computer networks." TI employees Jin-Meng Ho, Richard T. Baker, and Allison Winifred Hicks, who are listed as inventors on U.S. Patent No. 7,668,243, and others involved in the prosecution of the patent, including Dennis Moore, Ira Matsil, and Abdul Zindani, have had knowledge of the '053 Patent at least as of November 6, 2012.

61. Far North Patents has been damaged as a result of the infringing conduct by TI alleged above. Thus, TI is liable to Far North Patents in an amount that adequately compensates it for such infringements, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

62. Far North Patents and/or its predecessors-in-interest have satisfied all statutory obligations required to collect pre-filing damages for the full period allowed by law for infringement of the '053 Patent.

COUNT V

DIRECT INFRINGEMENT OF U.S. PATENT NO. 6,246,702

63. On June 12, 2001, United States Patent No. 6,246,702 ("the '702 Patent") was duly and legally issued by the United States Patent and Trademark Office for an invention entitled "Methods and Apparatus for Providing Quality-of-Service Guarantees in Computer Networks."

64. Far North Patents is the owner of the '702 Patent, with all substantive rights in and to that patent, including the sole and exclusive right to prosecute this action and enforce the '702 Patent against infringers, and to collect damages for all relevant times.

65. TI made, had made, used, imported, provided, supplied, distributed, sold, and/or offered for sale products and/or systems including, for example, its TI AM654 SoC Gigabit Ethernet Switch and AM654x and AM652x Sitara Processor families of products that include advanced quality of service capabilities (collectively, "accused products").

3.3.4.17. AM65x CPSW2g

The TI AM654 SoC Gigabit Ethernet Switch subsystem (CPSW NUSS) has two ports and provides Ethernet packet communication for the device. It supports MII interfaces the Reduced Gigabit Media Independent Interface (RGMII), Reduced Media Independent Interface (RMII), and the Management Data Input/Output (MDIO) interface for physical layer device (PHY) management.

(Source : http://software-dl.ti.com/processor-sdk-linux/esd/docs/latest/linux/Foundational_Components_Kernel_Drivers.html)

6.4.5.3 CPSW2G

The two-port Gigabit Ethernet MAC (MCU_CPSW0) subsystem provides Ethernet packet communication for the device and is configured in a similar manner as a two-port Ethernet switch. MCU_CPSW0 features the Reduced Gigabit Media Independent Interface (RGMII), Reduced Media Independent Interface (RMII), and the Management Data Input/Output (MDIO) interface for physical layer device (PHY) management.

The MCU_CPSW0 subsystem provides the following features:

- One Ethernet port (port 1) with selectable RGMII and RMII interfaces and an internal Communications Port Programming Interface (CPPI) port (port 0)
- Synchronous 10/100/1000 Mbit operation
- Flexible logical FIFO-based packet buffer structure
- Eight priority level Quality Of Service (QOS) support (802.1p)
- Support for Audio/Video Bridging (P802.1Qav/D6.0)
- Support for IEEE 1588 Clock Synchronization (2008 Annex D, Annex E and Annex F)
  - Timestamp module capable of time stamping external timesync events like Pulse-Per-Second and also generating Pulse-Per-Second outputs
  - CPTS module that supports time stamping for IEEE1588 with support for 4 hardware push events and generation of compare output pulses
- DSCP Priority Mapping (IPv4 and IPv6)
- Energy Efficient Ethernet (EEE) support (802.3az)
- Flow Control (802.3x) Support
- Non Blocking switch fabric
- Time Sensitive Network Support
  - IEEE P902.3br/D2.0 Interspersing Express Traffic
  - IEEE 802.1Qbv/D2.2 Enhancements for Scheduled Traffic

(Source : http://www.ti.com/lit/ds/symlink/am6548.pdf)

Texas Instruments

AM6548, AM6528, AM6546
AM6526, AM6527

SPRSP08H – NOVEMBER 2017 – REVISED JUNE 2019

AM654x, AM652x Sitara™ Processors

(Source : http://www.ti.com/lit/ds/symlink/am6548.pdf)

802.1Qbv – Enhancements for scheduled traffic

Time-aware shaper (TAS) makes switches aware of the cycle time for real-time traffic. A per-egress port scheduler for packets creates a periodic window during which there is no interfering traffic.

TI's TSN implementation for Sitara processors supports TAS. TAS is mostly a hardware feature, with a software stack configuring the hardware shaper in each bridge port and talker.

(Source : http://www.ti.com/lit/wp/spry316a/spry316a.pdf)

peripherals
- Internal MCSPI connection to the rest of SoC

Security:

- Secure boot supported
  - Hardware-enforced root-of-trust
  - Support to switch root-of-trust via backup key
  - Support for takeover protection, IP protection, and anti-roll back protection
- Cryptographic acceleration supported
  - Session-aware cryptographic engine with ability to auto-switch key-material based on incoming data stream
  - Supports cryptographic cores
    - AES – 128/192/256 bits key sizes
    - 3DES – 56/112/168 bits key sizes
    - MD5, SHA1
    - SHA2 – 224/256/384/512
    - DRBG with true random number generator
    - PKA (public key accelerator) to assist in RSA/ECC processing
  - DMA support
- Debugging security
  - Secure software controlled debug access
  - Security aware debugging

- Ring Accelerator (RA)
- Unified DMA (UDMA)
- Up to 2 Timer Managers (TM) (1024 timers each)

Multimedia:

- Display subsystem
  - Two fully input-mapped overlay managers associated with two display outputs
  - One port MIPI® DPI parallel interface
  - One port OLDI
- PowerVR® SGX544-MP1 3D Graphics Processing Unit (GPU)
- One Camera Serial Interface-2 (MIPI CSI-2)
- One port video capture: BT.656/1120 (no embedded sync)

High-speed interfaces:

- One Gigabit Ethernet (CPSW) interface supporting
  - RMII (10/100) or RGMII (10/100/1000)
  - IEEE1588 (2008 Annex D, Annex E, Annex F) with 802.1AS PTP
  - Audio/video bridging (P802.1Qav/D6.0)
  - Energy-efficient Ethernet (802.3az)
  - Jumbo frames (2024 bytes)
  - Clause 45 MDIO PHY management

(Source : http://www.ti.com/lit/ds/symlink/am6548.pdf)

6.4.5.3 CPSW2G

The two-port Gigabit Ethernet MAC (MCU_CPSW0) subsystem provides Ethernet packet communication for the device and is configured in a similar manner as a two-port Ethernet switch. MCU_CPSW0 features the Reduced Gigabit Media Independent Interface (RGMII), Reduced Media Independent Interface (RMII), and the Management Data Input/Output (MDIO) interface for physical layer device (PHY) management.

The MCU_CPSW0 subsystem provides the following features:

- One Ethernet port (port 1) with selectable RGMII and RMII interfaces and an internal Communications Port Programming Interface (CPPI) port (port 0)
- Synchronous 10/100/1000 Mbit operation
- Flexible logical FIFO-based packet buffer structure
- Eight priority level Quality Of Service (QOS) support (802.1p)
- Support for Audio/Video Bridging (P802.1Qav/D6.0)
- Support for IEEE 1588 Clock Synchronization (2008 Annex D, Annex E and Annex F)
  - Timestamp module capable of time stamping external timesync events like Pulse-Per-Second and also generating Pulse-Per-Second outputs
  - CPTS module that supports time stamping for IEEE1588 with support for 4 hardware push events and generation of compare output pulses
- DSCP Priority Mapping (IPv4 and IPv6)
- Energy Efficient Ethernet (EEE) support (802.3az)
- Flow Control (802.3x) Support
- Non Blocking switch fabric
- Time Sensitive Network Support
  - IEEE P902.3br/D2.0 Interspersing Express Traffic
  - IEEE 802.1Qbv/D2.2 Enhancements for Scheduled Traffic

(Source : http://www.ti.com/lit/ds/symlink/am6548.pdf)

66. By doing so, TI has directly infringed (literally and/or under the doctrine of equivalents) at least Claim 27 of the '702 Patent. TI's infringement in this regard is ongoing.

67. TI has infringed the '702 Patent by using the accused products and thereby practicing a method for regulating traffic in an Ethernet network including real-time devices, non-real-time devices, a network medium, and a plurality of device adapters connected between the devices and the network medium, each of the device adapters including a clock. For example, the accused products are used by TI to implement the IEEE 802.1Q standard. IEEE standard 802.1Q (Qbv) implements a method for scheduling traffic in time aware Local Area Network (Ethernet network). The time aware network includes multiple end points (devices) and bridges that includes ports (device adapters). The endpoint and bridges are connected via interconnects (network medium). Also, each time aware bridge including port is a boundary

clock. The endpoints transmit data that is a mix of time-critical traffic and other traffic, i.e, real time data and non-real time data. The end point is either a real time device or a non-real time device. IEEE Std. 802.1AS™ is normative and essential to implement an IEEE Std. 802.1Q Compliant System.

1.1 Project Number: P802.1Qbv
1.2 Type of Document: Standard
1.3 Life Cycle: Full Use

2.1 Title: Standard for Local and metropolitan area networks--Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks Amendment: Enhancements for Scheduled Traffic

5.2.b. Scope of the project: This amendment specifies time-aware queue-draining procedures, managed objects and extensions to existing protocols that enable bridges and end stations to schedule the transmission of frames based on a synchronized time. Virtual Local Area Network (VLAN) tag encoded priority values are allocated allowing simultaneous support of scheduled traffic, credit-based shaper traffic and other bridged traffic over Local Area Networks (LANs).

(Source: http://www.ieee802.org/1/files/public/docs2014/bv-p802-1Qbv-par-modification-1114.pdf)

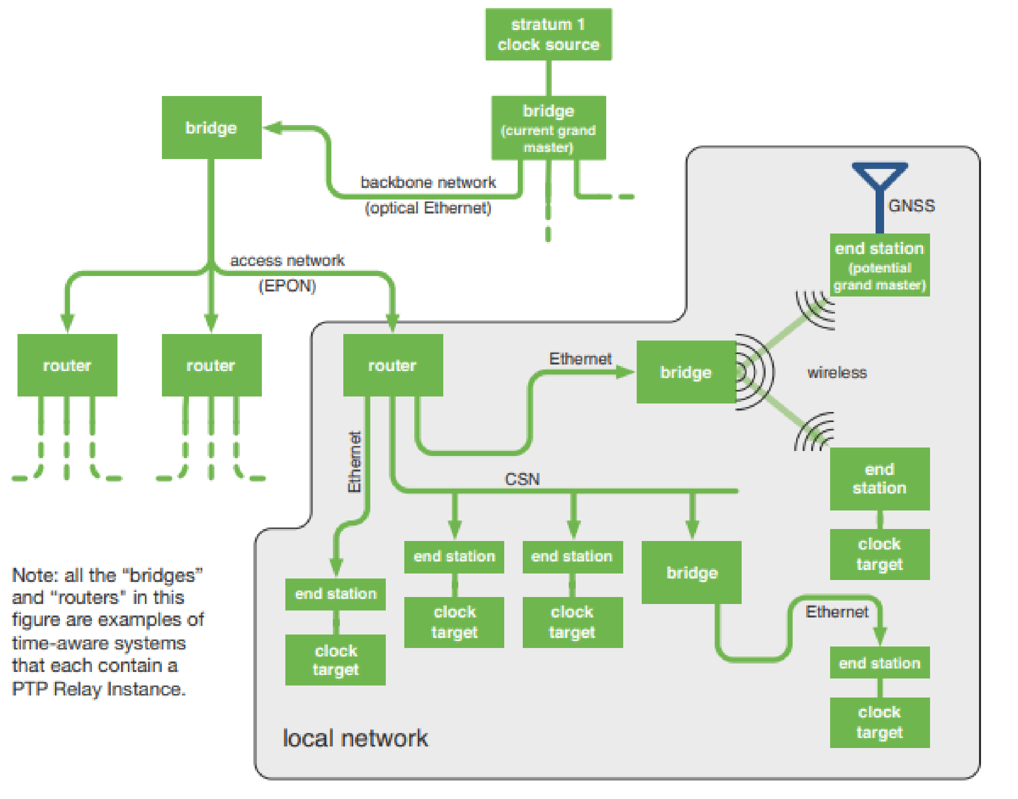

Figure 7-1—Time-aware network example

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

7.2 Architecture of a time-aware network

7.2.1 General

A time-aware network consists of a number of interconnected time-aware systems that support the gPTP defined within this standard. These time-aware systems can be any networking device, including, for example, bridges, routers, and end stations. A set of time-aware systems that are interconnected by gPTP-capable network elements is called a *gPTP network*. Each instance of gPTP that the time-aware systems support is in one *gPTP domain*, and the instances of gPTP are said to be part of that gPTP domain. A time-aware system can support, and therefore be part of, more than one gPTP domain. The entity of a single time-aware system that executes gPTP in one gPTP domain is called a PTP Instance. A time-aware system can contain multiple PTP Instances, which are each associated with a different gPTP domain. There are two

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

c) In gPTP there are only two types of PTP Instances: PTP End Instances and PTP Relay Instances, while IEEE 1588 has ordinary clocks, boundary clocks, end-to-end transparent clocks, and P2P transparent clocks. A PTP End Instance corresponds to an IEEE 1588 ordinary clock, and a PTP Relay Instance is a type of IEEE 1588 boundary clock where its operation is very tightly defined, so much so that a PTP Relay Instance with Ethernet ports can be shown to be mathematically equivalent to a P2P transparent clock in terms of how synchronization is performed, as shown in

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

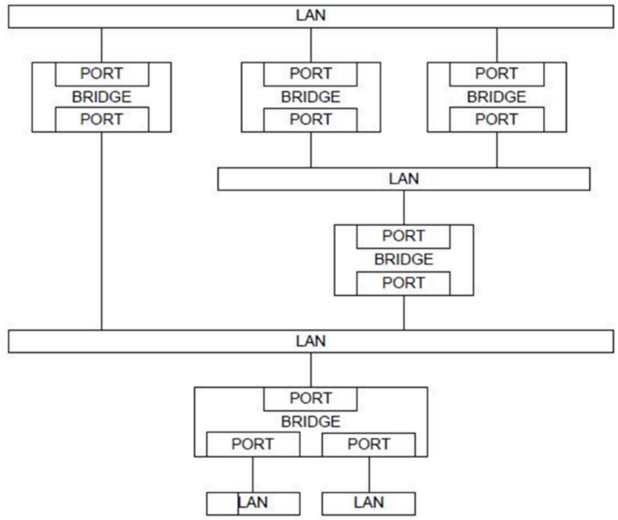

Figure 8-1—A Bridged Network

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

Traffic scheduling

This annex provides some background to the mechanisms provided in this standard for traffic scheduling, with the intent of providing some insight into the motivation for the provision of mechanisms for traffic scheduling and some of the ways that the mechanisms might be used.

Q.1 Motivation

Some applications have a need for frame delivery that is highly predictable in terms of the time at which frame transmission will occur, and the overall latency and jitter that will be experienced as the frame is propagated to its destination. Examples include industrial and automotive control applications, where data transmitted over the network is used to feed the parameters of control loops that are critical to the operation of the plant or machinery involved, and where frames carrying control data are transmitted on a repeating time schedule; late delivery of such frames can result in instability, inaccuracy, or failure of the operation of the control loops concerned. In some implementations, this need has been met by the provision of dedicated, highly engineered networks that are used solely for the transmission of time-critical control traffic; however, as the bandwidth occupied by such traffic is often low, and the cost of providing a dedicated control network can be high, it can be desirable to mix time-critical traffic with other classes of traffic in the same network, as long as such mixing can be achieved while still meeting the timing requirements of the time-critical traffic.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

IEEE Std 802.1Q-2018
IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in the text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI X3.159, American National Standards for Information Systems—Programming Language—C.[5]

IEEE Std 802®, IEEE Standard for Local and metropolitan area networks: Overview and Architecture.[6,7]

IEEE Std 802.1AB™, IEEE Standard for Local and metropolitan area networks—Station and Media Access Control Connectivity Discovery.

IEEE Std 802.1AC™, IEEE Standard for Local and metropolitan area networks—Media Access Control (MAC) Service Definition.

IEEE Std 802.1AE™, IEEE Standard for Local and metropolitan area networks—Media Access Control (MAC) Security.

IEEE Std 802.1AS™, IEEE Standard for Local and metropolitan area networks—Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

68. The methods practiced by TI's use of the accused products include defining a common time reference for the device adapters, said common time reference including a frame of time having a plurality of time phases, each of device adapters being uniquely assigned to one of said plurality of time phases, said plurality of time phases including a free-access phase. For example, the accused products are used by TI to implement the IEEE 802.1Q standard. The time aware bridged LAN use 802.1AS base time to maintain synchronized time (common time reference) for all the ports in the bridges (device adapters). The bridges containing ports schedule the transmission of traffic based on the synchronized time. Each port associated with a specific set of transmission queues includes a plurality of transmission gates. A transmission gate can be in a closed state or open state. The functionality of assigned time phases is achieved using open

gates transmitting data packets during transmission time. The functionality of free access phase is achieved when the gates are opened for transmission during any time.

1.1 Project Number: P802.1Qbv
1.2 Type of Document: Standard
1.3 Life Cycle: Full Use

2.1 Title: Standard for Local and metropolitan area networks--Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks Amendment: Enhancements for Scheduled Traffic

5.2.b. Scope of the project: This amendment specifies time-aware queue-draining procedures, managed objects and extensions to existing protocols that enable bridges and end stations to schedule the transmission of frames based on a synchronized time. Virtual Local Area Network (VLAN) tag encoded priority values are allocated allowing simultaneous support of scheduled traffic, credit-based shaper traffic and other bridged traffic over Local Area Networks (LANs).

(Source: http://www.ieee802.org/1/files/public/docs2014/bv-p802-1Qbv-par-modification-1114.pdf)

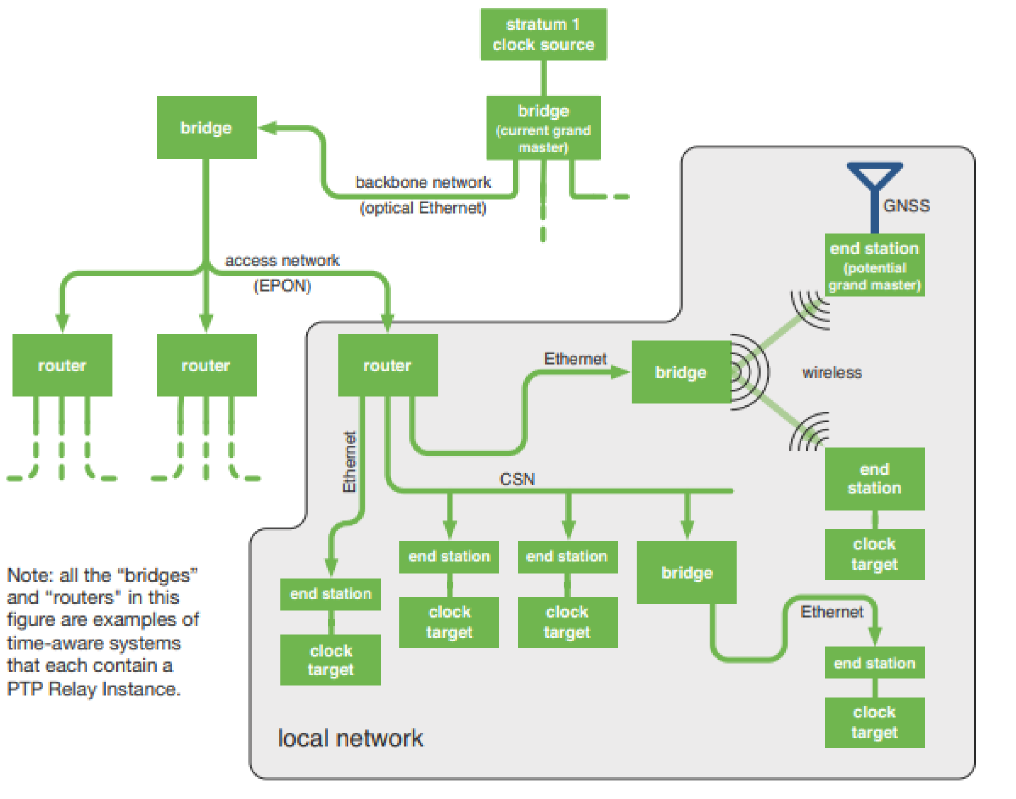

Figure 7-1—Time-aware network example

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

3.16 PTP End Instance: A PTP Instance that is capable of acting as the source of synchronized time on the network, or destination of synchronized time using the IEEE 802.1AS protocol, or both.

3.17 PTP Instance: A PTP Relay Instance or a PTP End Instance. A PTP Instance implements those portions of this standard indicated as applicable to a PTP Relay Instance or a PTP End Instance. Each PTP Instance operates in exactly one domain.

3.18 PTP Link: Within a domain, a network segment between two PTP Ports using the peer-to-peer delay mechanism of this standard. The peer-to-peer delay mechanism is designed to measure the propagation time over such a link.

NOTE—A PTP Link between PTP Ports of PTP Instances is also a gPTP Communication Path (see 3.9).

3.19 PTP Relay Instance: A PTP Instance that is capable of communicating synchronized time received on one port to other ports, using the IEEE 802.1AS protocol.

NOTE—A PTP Relay Instance could, for example, be contained in a bridge, a router, or a multi-port end station.

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

8.6.8.4 Enhancements for scheduled traffic

A Bridge or an end station may support enhancements that allow transmission from each queue to be scheduled relative to a known timescale. In order to achieve this, a transmission gate is associated with each queue; the state of the transmission gate determines whether or not queued frames can be selected for transmission (see Figure 8-12). For a given queue, the transmission gate can be in one of two states:

a) *Open*: Queued frames are selected for transmission, in accordance with the definition of the transmission selection algorithm associated with the queue.
b) *Closed*: Queued frames are not selected for transmission.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

8.6.8 Transmission selection

For each Port, frames are selected for transmission on the basis of the traffic classes that the Port supports and the operation of the transmission selection algorithms supported by the corresponding queues on that Port. For a given Port and traffic class, frames are selected from the corresponding queue for transmission if and only if

a) The operation of the transmission selection algorithm supported by that queue determines that there is a frame available for transmission; and

b) For each queue corresponding to a numerically higher value of traffic class supported by the Port, the operation of the transmission selection algorithm supported by that queue determines that there is no frame available for transmission.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

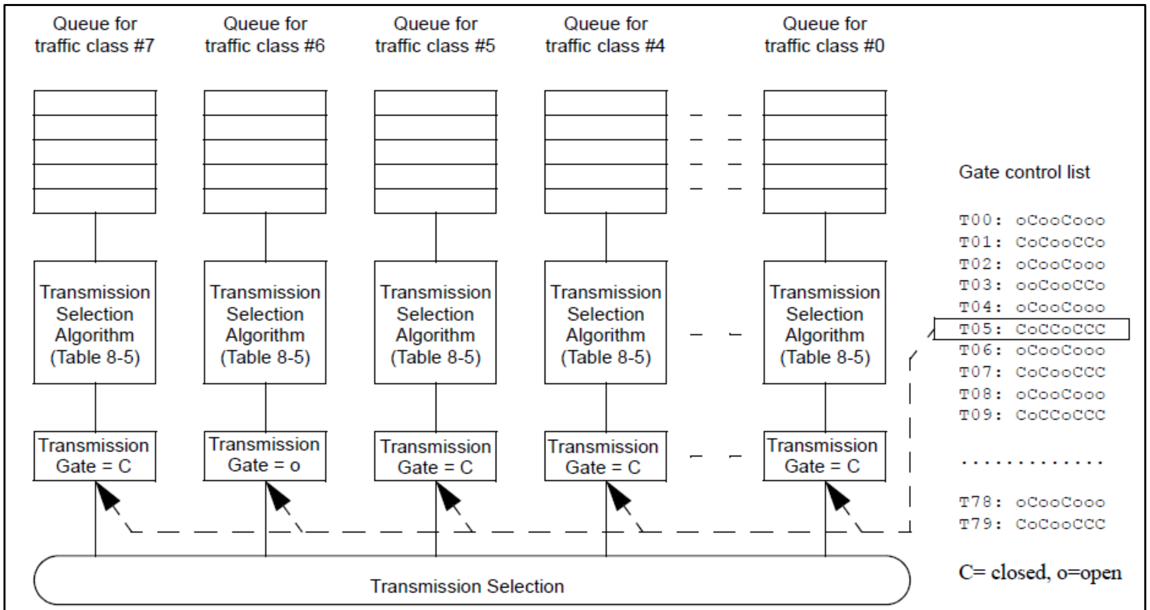

Figure 8-12—Transmission selection with gates

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

> A *gate control list* associated with each Port contains an ordered list of gate operations. Each gate operation changes the transmission gate state for the gate associated with each of the Port's traffic class queues. In an implementation that does not support enhancements for scheduled traffic, all gates are assumed to be permanently in the *open* state. Table 8-6 identifies the gate operation types, their parameters, and the actions that result from their execution. The state machines that control the execution of the gate control list, along with their variables and procedures, are specified in 8.6.9.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

69. The methods practiced by TI's use of the accused products include allowing a device adapter to transmit packets during said time phase uniquely assigned thereto and during said free-access phase. For example, the accused products are used by TI to implement the IEEE 802.1Q standard. The open gates assigned to the transmission queue of a port (device adapter) transmit the data packets during the transmission time. The transmission selection algorithm determines the transmission time. If the gates are in permanent open state, the data packets are transmitted from the gates during any time. The functionality of assigned time phases is achieved

using open gates transmitting data packets during transmission time. The functionality of free access phase is achieved when the gates are permanently opened for transmission during any time.

> **8.6.8.4 Enhancements for scheduled traffic**
>
> A Bridge or an end station may support enhancements that allow transmission from each queue to be scheduled relative to a known timescale. In order to achieve this, a transmission gate is associated with each queue; the state of the transmission gate determines whether or not queued frames can be selected for transmission (see Figure 8-12). For a given queue, the transmission gate can be in one of two states:
>
> a) *Open*: Queued frames are selected for transmission, in accordance with the definition of the transmission selection algorithm associated with the queue.
> b) *Closed*: Queued frames are not selected for transmission.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

> **3.4 transmission gate:** A gate that connects or disconnects the transmission selection function of the forwarding process from the queue, allowing or preventing it from selecting frames from that queue. The gate has two states, Open and Closed.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

> A *gate control list* associated with each Port contains an ordered list of gate operations. Each gate operation changes the transmission gate state for the gate associated with each of the Port's traffic class queues. In an implementation that does not support enhancements for scheduled traffic, all gates are assumed to be permanently in the *open* state. Table 8-6 identifies the gate operation types, their parameters, and the actions that result from their execution. The state machines that control the execution of the gate control list, along with their variables and procedures, are specified in 8.6.9.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

70. The methods practiced by TI's use of the accused products include designating one of said device adapters as a master timing device. For example, the accused products are used by TI to implement the IEEE 802.1Q standard. The ports of the time aware bridge (device

adapter) uses best master clock algorithm (BMCA) to determine a potential grandmaster port (master timing device).

7.2.2 Time-aware network consisting of a single gPTP domain

Figure 7-1 illustrates an example time-aware network consisting of a single gPTP domain, using all theabove network technologies (i.e., (c) - (f) of 7.2.1), where end stations on several local networks are connected to a grandmaster on a backbone network via an EPON access network.

Any PTP Instance with clock sourcing capabilities can be a potential grandmaster, so there is a selection method (the *best master clock algorithm*, or BMCA) that ensures that all of the PTP Instances in a gPTP domain use the same grandmaster.[12] The BMCA is largely identical to that used in IEEE Std 1588-2019,

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

10.3.1.1 Best master clock algorithm overview

In the BMCA (i.e., method (a) of 10.3.1), best master selection information is exchanged between PTP Instances of time-aware systems via Announce messages (see 10.5 and 10.6). Each Announce message contains time-synchronization spanning tree vector information that identifies one PTP Instance as the root of the time-synchronization spanning tree and, if the PTP Instance is grandmaster-capable, the grandmaster. Each PTP Instance in turn uses the information contained in the Announce messages it receives, along with its knowledge of itself, to compute which of the PTP Instances that it has knowledge of ought to be the root of the spanning tree and, if grandmaster-capable, the grandmaster. As part of constructing the time-synchronization spanning tree, each port of each PTP Instance is assigned a port state from Table 10-2 by state machines associated with the ports and with the PTP Instance as a whole.

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

11.1.3 Transport of time-synchronization information

The transport of time-synchronization information by a PTP Instance, using Sync and Follow_Up (or just Sync) messages, is illustrated in Figure 11-2. The mechanism is mathematically equivalent to the mechanism described in IEEE Std 1588-2019 for a peer-to-peer transparent clock that is syntonized (see 11.4.5.1, 11.5.1, and 11.5.2.2 of IEEE Std 1588-2019). However, as will be seen shortly, the processes of transporting synchronization by a peer-to-peer transparent clock that is syntonized and by a boundary clock are mathematically and functionally equivalent. The main functional difference between the two types of clocks is that the boundary clock participates in best master selection and invokes the BMCA, while the peer-to-peer transparent clock does not participate in best master selection and does not invoke the BMCA (and implementations of the two types of clocks can be different).

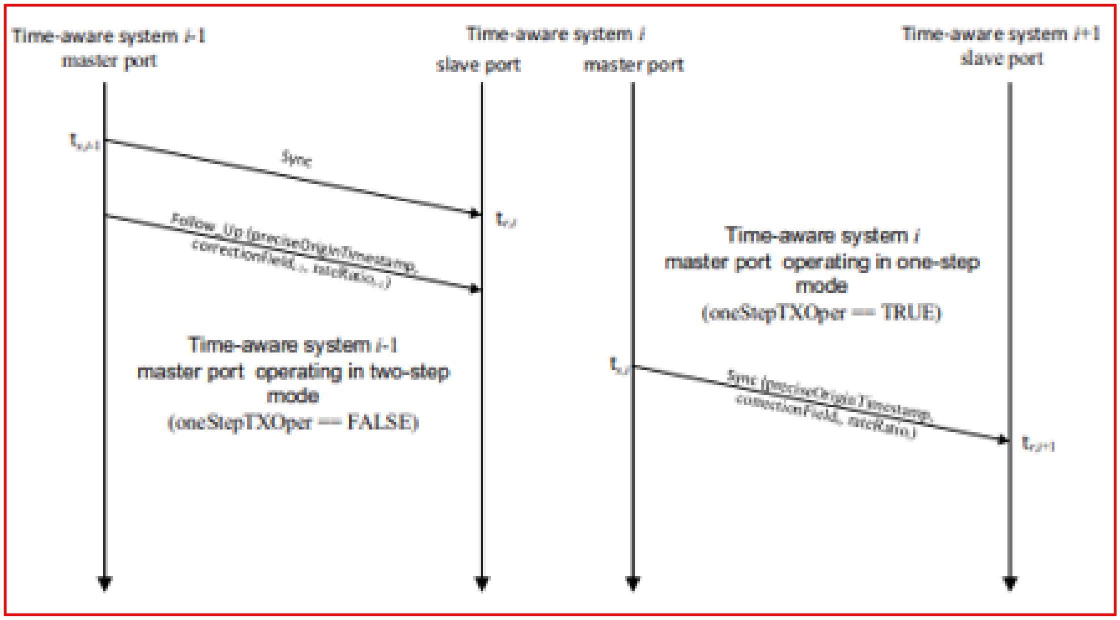

Figure 11-2—Transport of time-synchronization information

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

c) In gPTP there are only two types of PTP Instances: PTP End Instances and PTP Relay Instances, while IEEE 1588 has ordinary clocks, boundary clocks, end-to-end transparent clocks, and P2P transparent clocks. A PTP End Instance corresponds to an IEEE 1588 ordinary clock, and a PTP Relay Instance is a type of IEEE 1588 boundary clock where its operation is very tightly defined, so much so that a PTP Relay Instance with Ethernet ports can be shown to be mathematically equivalent to a P2P transparent clock in terms of how synchronization is performed, as shown in

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

71. The methods practiced by TI's use of the accused products include synchronizing the clocks of the remaining device adapters with said master timing device. For example, the

accused products are used by TI to implement the IEEE 802.1Q standard. The boundary clocks of the slave ports in the time aware bridges (remaining device adapters) are synchronized with the grandmaster boundary clock (master timing device).

> c) In gPTP there are only two types of PTP Instances: PTP End Instances and PTP Relay Instances, while IEEE 1588 has ordinary clocks, boundary clocks, end-to-end transparent clocks, and P2P transparent clocks. A PTP End Instance corresponds to an IEEE 1588 ordinary clock, and a PTP Relay Instance is a type of IEEE 1588 boundary clock where its operation is very tightly defined, so much so that a PTP Relay Instance with Ethernet ports can be shown to be mathematically equivalent to a P2P transparent clock in terms of how synchronization is performed, as shown in

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

> **3.16 PTP End Instance:** A PTP Instance that is capable of acting as the source of synchronized time on the network, or destination of synchronized time using the IEEE 802.1AS protocol, or both.
>
> **3.17 PTP Instance:** A PTP Relay Instance or a PTP End Instance. A PTP Instance implements those portions of this standard indicated as applicable to a PTP Relay Instance or a PTP End Instance. Each PTP Instance operates in exactly one domain.
>
> **3.18 PTP Link:** Within a domain, a network segment between two PTP Ports using the peer-to-peer delay mechanism of this standard. The peer-to-peer delay mechanism is designed to measure the propagation time over such a link.
>
> NOTE—A PTP Link between PTP Ports of PTP Instances is also a gPTP Communication Path (see 3.9).
>
> **3.19 PTP Relay Instance:** A PTP Instance that is capable of communicating synchronized time received on one port to other ports, using the IEEE 802.1AS protocol.
>
> NOTE—A PTP Relay Instance could, for example, be contained in a bridge, a router, or a multi-port end station.

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

11.1.3 Transport of time-synchronization information

The transport of time-synchronization information by a PTP Instance, using Sync and Follow_Up (or just Sync) messages, is illustrated in Figure 11-2. The mechanism is mathematically equivalent to the mechanism described in IEEE Std 1588-2019 for a peer-to-peer transparent clock that is syntonized (see 11.4.5.1, 11.5.1, and 11.5.2.2 of IEEE Std 1588-2019). However, as will be seen shortly, the processes of transporting synchronization by a peer-to-peer transparent clock that is syntonized and by a boundary clock are mathematically and functionally equivalent. The main functional difference between the two types of clocks is that the boundary clock participates in best master selection and invokes the BMCA, while the peer-to-peer transparent clock does not participate in best master selection and does not invoke the BMCA (and implementations of the two types of clocks can be different).

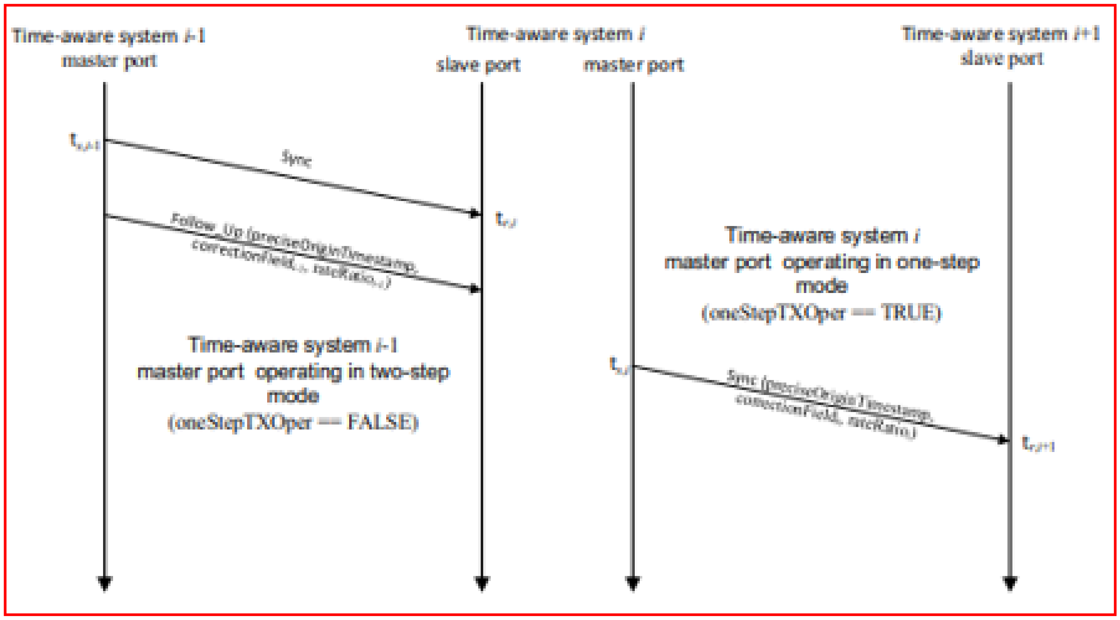

Figure 11-2—Transport of time-synchronization information

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

72. TI has had knowledge of the ‘702 Patent at least as of April 19, 2010, when it was cited by the examiner in an office action during the prosecution of U.S. Patent No. 7,930,121, entitled “Method and apparatus for synchronizing time stamps” and assigned to Texas Instruments Incorporated. That office action identified the ‘702 Patent as pertinent to the applicant’s disclosure, stating that “Fellman et al. (U.S. Patent 6,246,702) teaches method and apparatus for providing quality-of-service guarantees in computer networks.” TI employees

Steven G. Brantley, James Richard McLean, and Francesco Cavaliere, who are listed as inventors on U.S. Patent No. 7,930,121, and others involved in the prosecution of the patent, including Guy Clinger and John J. Patti, have had knowledge of the ‘702 Patent at least as of April 19, 2010.

73. Far North Patents has been damaged as a result of the infringing conduct by TI alleged above. Thus, TI is liable to Far North Patents in an amount that adequately compensates it for such infringements, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

74. Far North Patents and/or its predecessors-in-interest have satisfied all statutory obligations required to collect pre-filing damages for the full period allowed by law for infringement of the ‘702 Patent.

COUNT VI

DIRECT INFRINGEMENT OF U.S. PATENT NO. 6,215,797

75. On April 10, 2001, United States Patent No. 6,215,797 (“the ‘797 Patent”) was duly and legally issued by the United States Patent and Trademark Office for an invention entitled “Methods and Apparatus for Providing Quality of Service Guarantees in Computer Networks.”

76. Far North Patents is the owner of the ‘797 Patent, with all substantive rights in and to that patent, including the sole and exclusive right to prosecute this action and enforce the ‘797 Patent against infringers, and to collect damages for all relevant times.

77. TI made, had made, used, imported, provided, supplied, distributed, sold, and/or offered for sale products and/or systems including, for example, its TI AM654 SoC Gigabit

Ethernet Switch and AM654x and AM652x Sitara Processor families of products that include advanced quality of service capabilities (collectively, "accused products").

3.3.4.17. AM65x CPSW2g

The TI AM654 SoC Gigabit Ethernet Switch subsystem (CPSW NUSS) has two ports and provides Ethernet packet communication for the device. It supports MII interfaces the Reduced Gigabit Media Independent Interface (RGMII), Reduced Media Independent Interface (RMII), and the Management Data Input/Output (MDIO) interface for physical layer device (PHY) management.

(Source : http://software-dl.ti.com/processor-sdk-linux/esd/docs/latest/linux/Foundational_Components_Kernel_Drivers.html)

6.4.5.3 CPSW2G

The two-port Gigabit Ethernet MAC (MCU_CPSW0) subsystem provides Ethernet packet communication for the device and is configured in a similar manner as a two-port Ethernet switch. MCU_CPSW0 features the Reduced Gigabit Media Independent Interface (RGMII), Reduced Media Independent Interface (RMII), and the Management Data Input/Output (MDIO) interface for physical layer device (PHY) management.

The MCU_CPSW0 subsystem provides the following features:

- One Ethernet port (port 1) with selectable RGMII and RMII interfaces and an internal Communications Port Programming Interface (CPPI) port (port 0)
- Synchronous 10/100/1000 Mbit operation
- Flexible logical FIFO-based packet buffer structure
- Eight priority level Quality Of Service (QOS) support (802.1p)
- Support for Audio/Video Bridging (P802.1Qav/D6.0)
- Support for IEEE 1588 Clock Synchronization (2008 Annex D, Annex E and Annex F)
  - Timestamp module capable of time stamping external timesync events like Pulse-Per-Second and also generating Pulse-Per-Second outputs
  - CPTS module that supports time stamping for IEEE1588 with support for 4 hardware push events and generation of compare output pulses
- DSCP Priority Mapping (IPv4 and IPv6)
- Energy Efficient Ethernet (EEE) support (802.3az)
- Flow Control (802.3x) Support
- Non Blocking switch fabric
- Time Sensitive Network Support
  - IEEE P902.3br/D2.0 Interspersing Express Traffic
  - IEEE 802.1Qbv/D2.2 Enhancements for Scheduled Traffic

(Source : http://www.ti.com/lit/ds/symlink/am6548.pdf)

TEXAS INSTRUMENTS

AM6548, AM6528, AM6546
AM6526, AM6527

SPRSP08H – NOVEMBER 2017 – REVISED JUNE 2019

AM654x, AM652x Sitara™ Processors

(Source : http://www.ti.com/lit/ds/symlink/am6548.pdf)

802.1Qbv – Enhancements for scheduled traffic

Time-aware shaper (TAS) makes switches aware of the cycle time for real-time traffic. A per-egress port scheduler for packets creates a periodic window during which there is no interfering traffic.

TI's TSN implementation for Sitara processors supports TAS. TAS is mostly a hardware feature, with a software stack configuring the hardware shaper in each bridge port and talker.

(Source : http://www.ti.com/lit/wp/spry316a/spry316a.pdf)

peripherals
- Internal MCSPI connection to the rest of SoC

Security:
- Secure boot supported
  - Hardware-enforced root-of-trust
  - Support to switch root-of-trust via backup key
  - Support for takeover protection, IP protection, and anti-roll back protection
- Cryptographic acceleration supported
  - Session-aware cryptographic engine with ability to auto-switch key-material based on incoming data stream
  - Supports cryptographic cores
    - AES – 128/192/256 bits key sizes
    - 3DES – 56/112/168 bits key sizes
    - MD5, SHA1
    - SHA2 – 224/256/384/512
    - DRBG with true random number generator
    - PKA (public key accelerator) to assist in RSA/ECC processing
  - DMA support
- Debugging security
  - Secure software controlled debug access
  - Security aware debugging

  - Ring Accelerator (RA)
  - Unified DMA (UDMA)
  - Up to 2 Timer Managers (TM) (1024 timers each)

Multimedia:
- Display subsystem
  - Two fully input-mapped overlay managers associated with two display outputs
  - One port MIPI® DPI parallel interface
  - One port OLDI
- PowerVR® SGX544-MP1 3D Graphics Processing Unit (GPU)
- One Camera Serial Interface-2 (MIPI CSI-2)
- One port video capture: BT.656/1120 (no embedded sync)

High-speed interfaces:
- One Gigabit Ethernet (CPSW) interface supporting
  - RMII (10/100) or RGMII (10/100/1000)
  - IEEE1588 (2008 Annex D, Annex E, Annex F) with 802.1AS PTP
  - Audio/video bridging (P802.1Qav/D6.0)
  - Energy-efficient Ethernet (802.3az)
  - Jumbo frames (2024 bytes)
  - Clause 45 MDIO PHY management

(Source : http://www.ti.com/lit/ds/symlink/am6548.pdf)

6.4.5.3 CPSW2G

The two-port Gigabit Ethernet MAC (MCU_CPSW0) subsystem provides Ethernet packet communication for the device and is configured in a similar manner as a two-port Ethernet switch. MCU_CPSW0 features the Reduced Gigabit Media Independent Interface (RGMII), Reduced Media Independent Interface (RMII), and the Management Data Input/Output (MDIO) interface for physical layer device (PHY) management.

The MCU_CPSW0 subsystem provides the following features:

- One Ethernet port (port 1) with selectable RGMII and RMII interfaces and an internal Communications Port Programming Interface (CPPI) port (port 0)
- Synchronous 10/100/1000 Mbit operation
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- DSCP Priority Mapping (IPv4 and IPv6)
- Energy Efficient Ethernet (EEE) support (802.3az)
- Flow Control (802.3x) Support
- Non Blocking switch fabric
- Time Sensitive Network Support
  - IEEE P902.3br/D2.0 Interspersing Express Traffic
  - IEEE 802.1Qbv/D2.2 Enhancements for Scheduled Traffic

(Source : http://www.ti.com/lit/ds/symlink/am6548.pdf)

78. By doing so, TI has directly infringed (literally and/or under the doctrine of equivalents) at least Claim 30 of the '797 Patent. TI's infringement in this regard is ongoing.

79. TI has infringed the '797 Patent by using the accused products and thereby practicing a method for regulating traffic in a network including devices for generating packets of data, a network medium for carrying the packets, and a plurality of device adapters connected between the devices and the network medium. For example, the accused products are used by TI to implement the IEEE 802.1Q standard. IEEE standard 802.1Q (Qbv) implements a method for scheduling traffic in time aware Local Area Network. The time aware network includes multiple end points that transmit data packets and bridges that includes ports (device adapters). The interconnects (network medium) carry the transmitted data packets. The endpoints and bridges are connected via interconnects.

1.1 Project Number: P802.1Qbv
1.2 Type of Document: Standard
1.3 Life Cycle: Full Use

2.1 Title: Standard for Local and metropolitan area networks--Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks Amendment: Enhancements for Scheduled Traffic

5.2.b. Scope of the project: This amendment specifies time-aware queue-draining procedures, managed objects and extensions to existing protocols that enable bridges and end stations to schedule the transmission of frames based on a synchronized time. Virtual Local Area Network (VLAN) tag encoded priority values are allocated allowing simultaneous support of scheduled traffic, credit-based shaper traffic and other bridged traffic over Local Area Networks (LANs).

(Source: http://www.ieee802.org/1/files/public/docs2014/bv-p802-1Qbv-par-modification-1114.pdf)

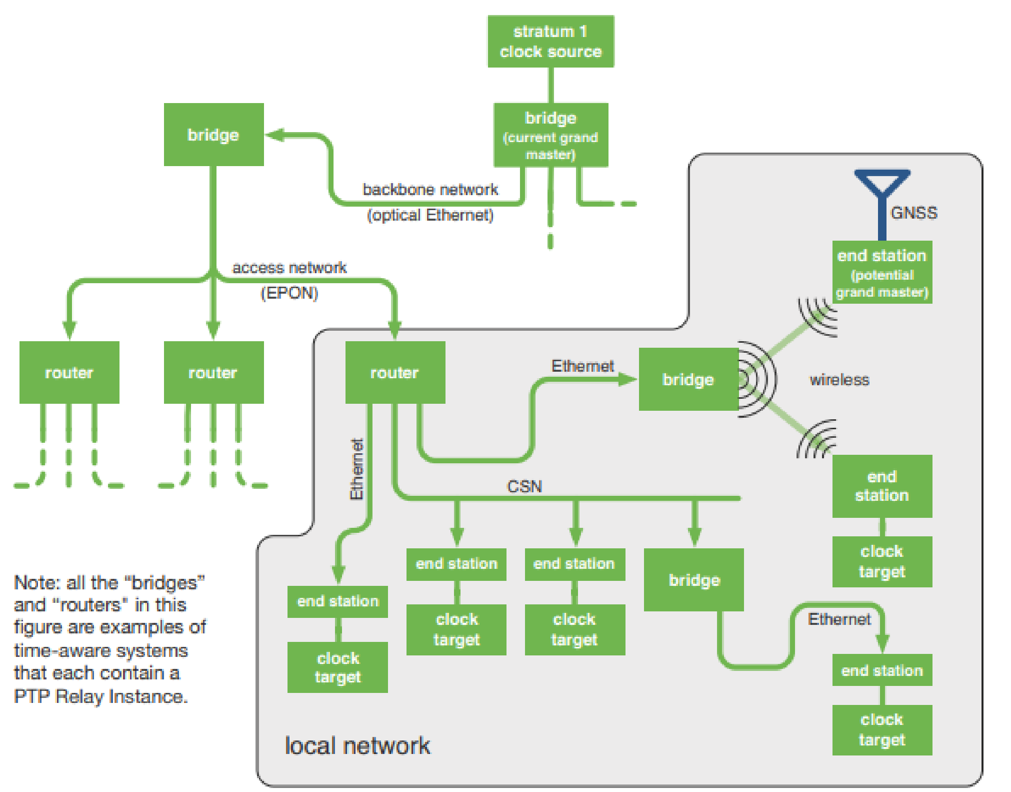

Figure 7-1—Time-aware network example

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

7.2 Architecture of a time-aware network

7.2.1 General

A time-aware network consists of a number of interconnected time-aware systems that support the gPTP defined within this standard. These time-aware systems can be any networking device, including, for example, bridges, routers, and end stations. A set of time-aware systems that are interconnected by gPTP-capable network elements is called a *gPTP network*. Each instance of gPTP that the time-aware systems support is in one *gPTP domain*, and the instances of gPTP are said to be part of that gPTP domain. A time-aware system can support, and therefore be part of, more than one gPTP domain. The entity of a single time-aware system that executes gPTP in one gPTP domain is called a PTP Instance. A time-aware system can contain multiple PTP Instances, which are each associated with a different gPTP domain. There are two

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

Traffic scheduling

This annex provides some background to the mechanisms provided in this standard for traffic scheduling, with the intent of providing some insight into the motivation for the provision of mechanisms for traffic scheduling and some of the ways that the mechanisms might be used.

Q.1 Motivation

Some applications have a need for frame delivery that is highly predictable in terms of the time at which frame transmission will occur, and the overall latency and jitter that will be experienced as the frame is propagated to its destination. Examples include industrial and automotive control applications, where data transmitted over the network is used to feed the parameters of control loops that are critical to the operation of the plant or machinery involved, and where frames carrying control data are transmitted on a repeating time schedule; late delivery of such frames can result in instability, inaccuracy, or failure of the operation of the control loops concerned. In some implementations, this need has been met by the provision of dedicated, highly engineered networks that are used solely for the transmission of time-critical control traffic; however, as the bandwidth occupied by such traffic is often low, and the cost of providing a dedicated control network can be high, it can be desirable to mix time-critical traffic with other classes of traffic in the same network, as long as such mixing can be achieved while still meeting the timing requirements of the time-critical traffic.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

b) gPTP specifies a media-independent sublayer that simplifies the integration within a single timing domain of multiple different networking technologies with radically different media access protocols. gPTP specifies a media-dependent sublayer for each medium. The information exchanged between PTP Instances has been generalized to support different packet formats and management schemes appropriate to the particular networking technology. IEEE Std 1588-2019, on the other

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

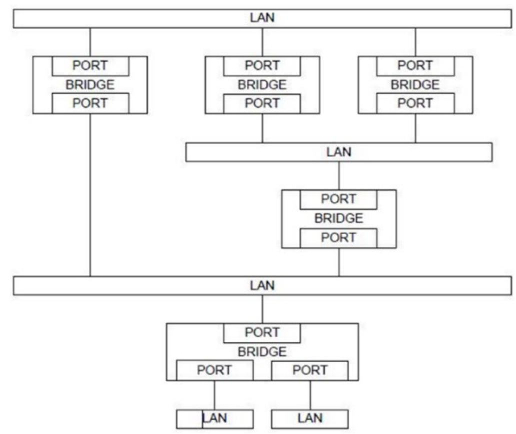

Figure 8-1—A Bridged Network

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

80. The methods practiced by TI's use of the accused products include defining a common time reference for the device adapters, said common time reference including a frame of time having a plurality of time phases, each device adapter being uniquely assigned to one of said plurality of time phases, said plurality of time phases including a free-access phase. For example, the accused products are used by TI to implement the IEEE 802.1Q standard. The time aware bridged LAN uses 802.1AS base time to maintain synchronized time (common time reference) for all the ports in the bridges (device adapters). The bridges containing ports are scheduled for transmission of traffic based on the synchronized time. Each port associated with a specific set of transmission queues includes a plurality of transmission gates. A transmission gate can be in a closed state or open state. The functionality of assigned time phases is achieved using open gates transmitting data packets during transmission time. The functionality of free access phase is achieved when the gates are opened for transmission during any time. IEEE Std. 802.1AS™-2011 is normative and essential to implement an IEEE Std. 802.1Q Compliant System.

1.1 Project Number: P802.1Qbv
1.2 Type of Document: Standard
1.3 Life Cycle: Full Use

2.1 Title: Standard for Local and metropolitan area networks--Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks Amendment: Enhancements for Scheduled Traffic

5.2.b. Scope of the project: This amendment specifies time-aware queue-draining procedures, managed objects and extensions to existing protocols that enable bridges and end stations to schedule the transmission of frames based on a synchronized time. Virtual Local Area Network (VLAN) tag encoded priority values are allocated allowing simultaneous support of scheduled traffic, credit-based shaper traffic and other bridged traffic over Local Area Networks (LANs).

(Source: http://www.ieee802.org/1/files/public/docs2014/bv-p802-1Qbv-par-modification-1114.pdf)

IEEE Std 802.1Q-2018
IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in the text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI X3.159, American National Standards for Information Systems—Programming Language—C.[5]

IEEE Std 802®, IEEE Standard for Local and metropolitan area networks: Overview and Architecture.[6,7]

IEEE Std 802.1AB™, IEEE Standard for Local and metropolitan area networks—Station and Media Access Control Connectivity Discovery.

IEEE Std 802.1AC™, IEEE Standard for Local and metropolitan area networks—Media Access Control (MAC) Service Definition.

IEEE Std 802.1AE™, IEEE Standard for Local and metropolitan area networks—Media Access Control (MAC) Security.

IEEE Std 802.1AS™, IEEE Standard for Local and metropolitan area networks—Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

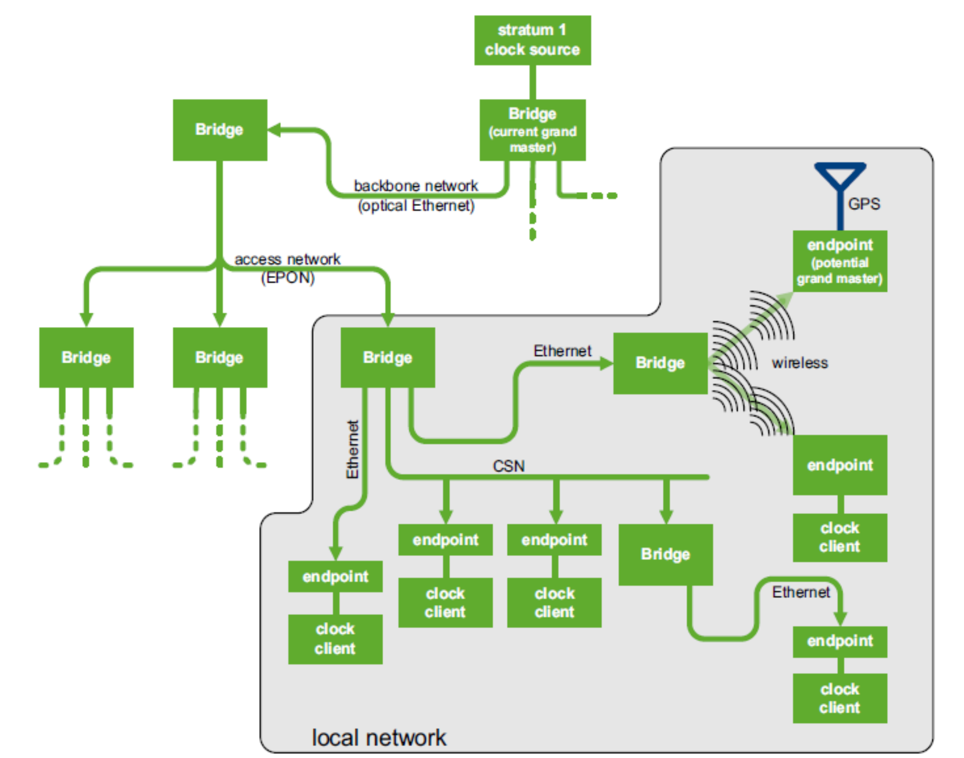

Figure 7-1—Time-aware network example

(Source: IEEE Standard for Local and metropolitan area networks - Timing and Synchronization for Time - Sensitive Applications in Bridged Local Area Networks - IEEE Std 802.1AS™-2011)

3.16 PTP End Instance: A PTP Instance that is capable of acting as the source of synchronized time on the network, or destination of synchronized time using the IEEE 802.1AS protocol, or both.

3.17 PTP Instance: A PTP Relay Instance or a PTP End Instance. A PTP Instance implements those portions of this standard indicated as applicable to a PTP Relay Instance or a PTP End Instance. Each PTP Instance operates in exactly one domain.

3.18 PTP Link: Within a domain, a network segment between two PTP Ports using the peer-to-peer delay mechanism of this standard. The peer-to-peer delay mechanism is designed to measure the propagation time over such a link.

NOTE—A PTP Link between PTP Ports of PTP Instances is also a gPTP Communication Path (see 3.9).

3.19 PTP Relay Instance: A PTP Instance that is capable of communicating synchronized time received on one port to other ports, using the IEEE 802.1AS protocol.

NOTE—A PTP Relay Instance could, for example, be contained in a bridge, a router, or a multi-port end station.

(Source: https://1.ieee802.org/wp-content/uploads/2019/03/802-1AS-rev-d8-0.pdf)

8.6.8.4 Enhancements for scheduled traffic

A Bridge or an end station may support enhancements that allow transmission from each queue to be scheduled relative to a known timescale. In order to achieve this, a transmission gate is associated with each queue; the state of the transmission gate determines whether or not queued frames can be selected for transmission (see Figure 8-12). For a given queue, the transmission gate can be in one of two states:

a) *Open*: Queued frames are selected for transmission, in accordance with the definition of the transmission selection algorithm associated with the queue.
b) *Closed*: Queued frames are not selected for transmission.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

8.6.8 Transmission selection

For each Port, frames are selected for transmission on the basis of the traffic classes that the Port supports and the operation of the transmission selection algorithms supported by the corresponding queues on that Port. For a given Port and traffic class, frames are selected from the corresponding queue for transmission if and only if

a) The operation of the transmission selection algorithm supported by that queue determines that there is a frame available for transmission; and

b) For each queue corresponding to a numerically higher value of traffic class supported by the Port, the operation of the transmission selection algorithm supported by that queue determines that there is no frame available for transmission.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

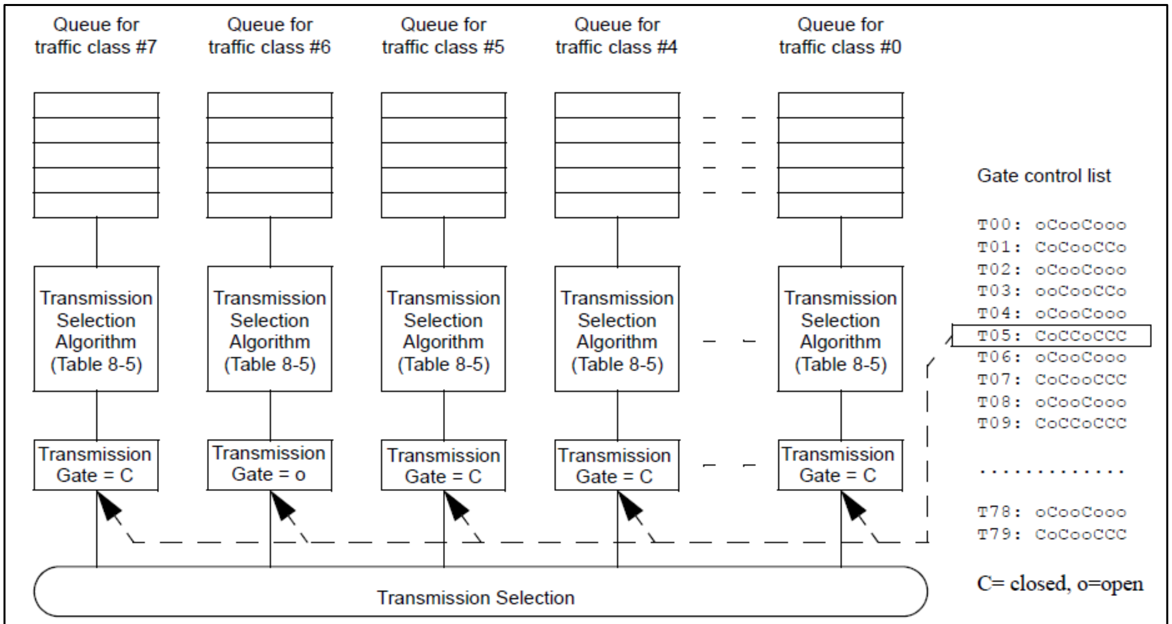

Figure 8-12—Transmission selection with gates

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

> A *gate control list* associated with each Port contains an ordered list of gate operations. Each gate operation changes the transmission gate state for the gate associated with each of the Port's traffic class queues. In an implementation that does not support enhancements for scheduled traffic, all gates are assumed to be permanently in the *open* state. Table 8-6 identifies the gate operation types, their parameters, and the actions that result from their execution. The state machines that control the execution of the gate control list, along with their variables and procedures, are specified in 8.6.9.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

81. The methods practiced by TI's use of the accused products include allowing a device adapter to transmit packets during said time phase uniquely assigned thereto and during said free-access phase. For example, the accused products are used by TI to implement the IEEE 802.1Q standard. The open gates assigned to the transmission queue of a port (device adapter) transmit the data packets during the transmission time. The transmission selection algorithm determines the transmission time. If the gates are in permanent open state, the data packets are transmitted from the gates during any time. The functionality of assigned time phases is achieved

using open gates transmitting data packets during transmission time. The functionality of free access phase is achieved when the gates are permanently opened for transmission during any time.

> **8.6.8.4 Enhancements for scheduled traffic**
>
> A Bridge or an end station may support enhancements that allow transmission from each queue to be scheduled relative to a known timescale. In order to achieve this, a transmission gate is associated with each queue; the state of the transmission gate determines whether or not queued frames can be selected for transmission (see Figure 8-12). For a given queue, the transmission gate can be in one of two states:
>
> a) *Open*: Queued frames are selected for transmission, in accordance with the definition of the transmission selection algorithm associated with the queue.
> b) *Closed*: Queued frames are not selected for transmission.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

> **3.4 transmission gate:** A gate that connects or disconnects the transmission selection function of the forwarding process from the queue, allowing or preventing it from selecting frames from that queue. The gate has two states, Open and Closed.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

11.1.3 Transport of time-synchronization information

The transport of time-synchronization information by a PTP Instance, using Sync and Follow_Up (or just Sync) messages, is illustrated in Figure 11-2. The mechanism is mathematically equivalent to the mechanism described in IEEE Std 1588-2019 for a peer-to-peer transparent clock that is syntonized (see 11.4.5.1, 11.5.1, and 11.5.2.2 of IEEE Std 1588-2019). However, as will be seen shortly, the processes of transporting synchronization by a peer-to-peer transparent clock that is syntonized and by a boundary clock are mathematically and functionally equivalent. The main functional difference between the two types of clocks is that the boundary clock participates in best master selection and invokes the BMCA, while the peer-to-peer transparent clock does not participate in best master selection and does not invoke the BMCA (and implementations of the two types of clocks can be different).

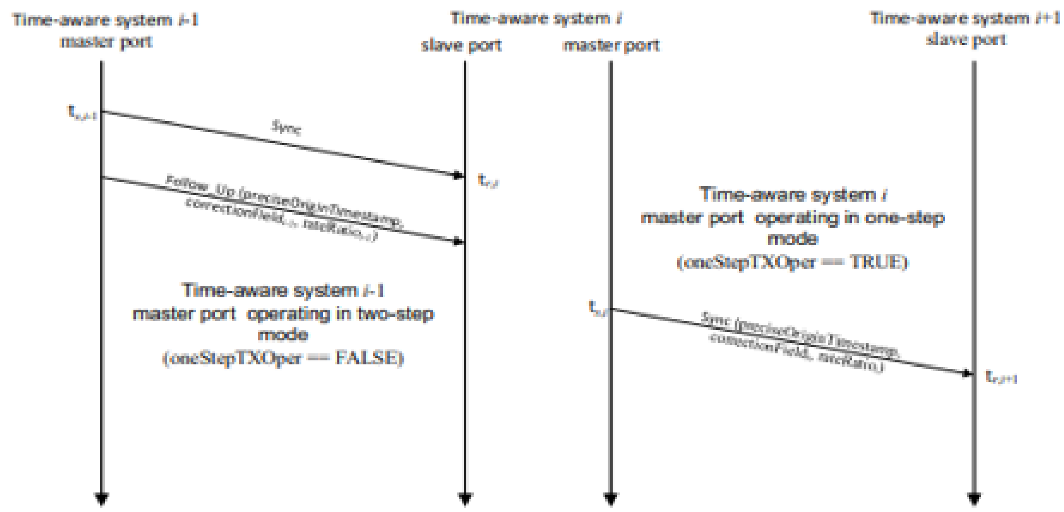

Figure 11-2—Transport of time-synchronization information

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

> A *gate control list* associated with each Port contains an ordered list of gate operations. Each gate operation changes the transmission gate state for the gate associated with each of the Port's traffic class queues. In an implementation that does not support enhancements for scheduled traffic, all gates are assumed to be permanently in the *open* state. Table 8-6 identifies the gate operation types, their parameters, and the actions that result from their execution. The state machines that control the execution of the gate control list, along with their variables and procedures, are specified in 8.6.9.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

82. The methods practiced by TI's use of the accused products include cyclically repeating said frame. For example, the accused products are used by TI to implement the IEEE

802.1Q standard. IEEE Std. 802.1Q-2018 supports cyclic queuing and forwarding structures to create synchronized frames and gates that are repeated periodically (Annex T).

Cyclic queuing and forwarding[53]

T.1 Overview of CQF

Cyclic queuing and forwarding (CQF) is a method of traffic shaping that can deliver deterministic, and easily calculated, latency for time-sensitive traffic streams. As the name implies, the principle underlying CQF is that stream traffic is transmitted and queued for transmission along a network path in a cyclic manner. Time is divided into numbered time intervals *i*, *i*+1, *i*+2, ... *i*+*N*, each of duration *d*. Frames transmitted by a Bridge, *Alice*, during time interval *i* are received by a downstream Bridge, *Bob*, during time interval *i* and are transmitted onwards by *Bob* towards Bridge *Charlie* during time interval *i*+1, and so on. A starting assumption is that, for a given traffic class, all Bridges and all end stations connected to a given bridge have a common understanding (to a known accuracy) of the start time of cycle *i*, and the cycle duration, *d*.

Frames transmitted by *Alice* during interval *i* are transmitted by *Bob* in interval *i*+1; the maximum possible delay experienced by a given frame is from the beginning of *i* to the end of *i*+1, or twice *d*. Similarly, the minimum possible delay experienced is from the end of *i* to the beginning of *i*+1, which is zero. More generally, the maximum delay experienced by a given frame is

$$(h+1) \times d$$

and the minimum delay experienced by a given frame is

$$(h-1) \times d$$

where *h* is the number of hops.

(Source: IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks- IEEE Std 802.1Q™-2018)

Traffic scheduling

This annex provides some background to the mechanisms provided in this standard for traffic scheduling, with the intent of providing some insight into the motivation for the provision of mechanisms for traffic scheduling and some of the ways that the mechanisms might be used.

Q.1 Motivation

Some applications have a need for frame delivery that is highly predictable in terms of the time at which frame transmission will occur, and the overall latency and jitter that will be experienced as the frame is propagated to its destination. Examples include industrial and automotive control applications, where data transmitted over the network is used to feed the parameters of control loops that are critical to the operation of the plant or machinery involved, and where frames carrying control data are transmitted on a repeating time schedule; late delivery of such frames can result in instability, inaccuracy, or failure of the operation of the control loops concerned. In some implementations, this need has been met by the provision of dedicated, highly engineered networks that are used solely for the transmission of time-critical control traffic; however, as the bandwidth occupied by such traffic is often low, and the cost of providing a dedicated control network can be high, it can be desirable to mix time-critical traffic with other classes of traffic in the same network, as long as such mixing can be achieved while still meeting the timing requirements of the time-critical traffic.

(Source: IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks Amendment 25: Enhancements for Scheduled Traffic (IEEE 802.1Qbv-2015))

83. TI has had knowledge of the '797 Patent at least as of the date when it was notified of the filing of this action.

84. Far North Patents has been damaged as a result of the infringing conduct by TI alleged above. Thus, TI is liable to Far North Patents in an amount that adequately compensates it for such infringements, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

85. Far North Patents and/or its predecessors-in-interest have satisfied all statutory obligations required to collect pre-filing damages for the full period allowed by law for infringement of the '797 Patent.

ADDITIONAL ALLEGATIONS REGARDING INFRINGEMENT

86. TI has also indirectly infringed the '105 Patent, the '437 Patent, the '230 Patent, the '053 Patent, the '702 Patent, and the '797 Patent by inducing others to directly infringe the '105 Patent, the '437 Patent, the '230 Patent, the '053 Patent, the '702 Patent, and the '797 Patent. TI has induced the end-users, TI's customers, to directly infringe (literally and/or under the doctrine of equivalents) the '105 Patent, the '437 Patent, the '230 Patent, the '053 Patent, the '702 Patent, and the '797 Patent by using the accused products.

87. TI took active steps, directly and/or through contractual relationships with others, with the specific intent to cause them to use the accused products in a manner that infringes one or more claims of the patents-in-suit, including, for example, Claims 1 and 23 of the '105 Patent, Claim 9 of the '437 Patent, Claim 1 of the '230 Patent, Claims 1 and 14 of the '053 Patent, Claim 27 of the '702 Patent, and Claim 30 of the '797 Patent.

88. Such steps by TI included, among other things, advising or directing customers and end-users to use the accused products in an infringing manner; advertising and promoting the use of the accused products in an infringing manner; and/or distributing instructions that guide users to use the accused products in an infringing manner.

89. TI has performed these steps, which constitute induced infringement, with the knowledge of the '105 Patent, the '437 Patent, the '230 Patent, the '053 Patent, the '702 Patent, and the '797 Patent and with the knowledge that the induced acts constitute infringement.

90. TI was and is aware that the normal and customary use of the accused products by TI's customers would infringe the '105 Patent, the '437 Patent, the '230 Patent, the '053 Patent, the '702 Patent, and the '797 Patent. TI's inducement is ongoing.

91. TI has also induced its affiliates, or third-party manufacturers, shippers, distributors, retailers, or other persons acting on its or its affiliates' behalf, to directly infringe (literally and/or under the doctrine of equivalents) the '105 Patent, the '437 Patent, the '230 Patent, the '053 Patent, the '702 Patent, and the '797 Patent by importing, selling or offering to sell the accused products.

92. TI has at least a significant role in placing the accused products in the stream of commerce in Texas and elsewhere in the United States.

93. TI directs or controls the making of accused products and their shipment to the United States, using established distribution channels, for sale in Texas and elsewhere within the United States.

94. TI directs or controls the sale of the accused products into established United States distribution channels, including sales to nationwide retailers.

95. TI's established United States distribution channels include one or more United States based affiliates (e.g., at least Texas Instruments Austin Incorporated, Texas Instruments Richardson LLC, and Texas Instruments Tucson Corporation).

96. TI directs or controls the sale of the accused products online and in nationwide retailers, including for sale in Texas and elsewhere in the United States, and expects and intends that the accused products will be so sold.

97. TI took active steps, directly and/or through contractual relationships with others, with the specific intent to cause such persons to import, sell, or offer to sell the accused products in a manner that infringes one or more claims of the patents-in-suit, including, for example, Claims 1 and 23 of the '105 Patent, Claim 9 of the '437 Patent, Claim 1 of the '230 Patent,

Claims 1 and 14 of the ‘053 Patent, Claim 27 of the ‘702 Patent, and Claim 30 of the ‘797 Patent.

98. Such steps by TI included, among other things, making or selling the accused products outside of the United States for importation into or sale in the United States, or knowing that such importation or sale would occur; and directing, facilitating, or influencing its affiliates, or third-party manufacturers, shippers, distributors, retailers, or other persons acting on its or their behalf, to import, sell, or offer to sell the accused products in an infringing manner.

99. TI performed these steps, which constitute induced infringement, with the knowledge of the ‘105 Patent, the ‘437 Patent, the ‘230 Patent, the ‘053 Patent, the ‘702 Patent, and the ‘797 Patent and with the knowledge that the induced acts would constitute infringement.

100. TI performed such steps in order to profit from the eventual sale of the accused products in the United States.

101. TI’s inducement is ongoing.

102. TI has also indirectly infringed by contributing to the infringement of the ‘105 Patent, the ‘437 Patent, the ‘230 Patent, the ‘053 Patent, the ‘702 Patent, and the ‘797 Patent. TI has contributed to the direct infringement of the ‘105 Patent, the ‘437 Patent, the ‘230 Patent, the ‘053 Patent, the ‘702 Patent, and the ‘797 Patent by the end-user of the accused products.

103. The accused products have special features that are specially designed to be used in an infringing way and that have no substantial uses other than ones that infringe the ‘105 Patent, the ‘437 Patent, the ‘230 Patent, the ‘053 Patent, the ‘702 Patent, and the ‘797 Patent, including, for example, Claims 1 and 23 of the ‘105 Patent, Claim 9 of the ‘437 Patent, Claim 1 of the ‘230 Patent, Claims 1 and 14 of the ‘053 Patent, Claim 27 of the ‘702 Patent, and Claim 30 of the ‘797 Patent.

104. The special features include advanced quality monitoring capabilities and advanced quality of service capabilities, used in a manner that infringes the '105 Patent, the '437 Patent, the '230 Patent, the '053 Patent, the '702 Patent, and the '797 Patent.

105. The special features constitute a material part of the invention of one or more of the claims of the '105 Patent, the '437 Patent, the '230 Patent, the '053 Patent, the '702 Patent, and the '797 Patent and are not staple articles of commerce suitable for substantial non-infringing use.

106. TI's contributory infringement is ongoing.

107. Furthermore, TI has a policy or practice of not reviewing the patents of others (including instructing its employees to not review the patents of others), and thus has been willfully blind of Far North Patents' patent rights. *See, e.g.*, M. Lemley, "Ignoring Patents," 2008 Mich. St. L. Rev. 19 (2008).

108. TI's actions are at least objectively reckless as to the risk of infringing valid patents and this objective risk was either known or should have been known by TI.

109. TI has knowledge of the '105 Patent, the '437 Patent, the '230 Patent, the '053 Patent, the '702 Patent, and the '797 Patent.

110. TI's customers have infringed the '105 Patent, the '437 Patent, the '230 Patent, the '053 Patent, the '702 Patent, and the '797 Patent.

111. TI encouraged its customers' infringement.

112. TI's direct and indirect infringement of the '105 Patent, the '437 Patent, the '230 Patent, the '053 Patent, the '702 Patent, and the '797 Patent is, has been, and/or continues to be willful, intentional, deliberate, and/or in conscious disregard of Far North Patents' rights under the patents.

113. Far North Patents has been damaged as a result of the infringing conduct by TI alleged above. Thus, TI is liable to Far North Patents in an amount that adequately compensates it for such infringements, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

JURY DEMAND

Far North Patents hereby requests a trial by jury on all issues so triable by right.

PRAYER FOR RELIEF

Far North Patents requests that the Court find in its favor and against TI, and that the Court grant Far North Patents the following relief:

a. Judgment that one or more claims of the '105 Patent, the '437 Patent, the '230 Patent, the '053 Patent, the '702 Patent, and the '797 Patent have been infringed, either literally and/or under the doctrine of equivalents, by TI and/or all others acting in concert therewith;

b. A permanent injunction enjoining TI and its officers, directors, agents, servants, affiliates, employees, divisions, branches, subsidiaries, parents, and all others acting in concert therewith from infringement of the '105 Patent, the '437 Patent, the '230 Patent, and the '053 Patent; or, in the alternative, an award of a reasonable ongoing royalty for future infringement of the '105 Patent, the '437 Patent, the '230 Patent, and the '053 Patent by such entities;

c. Judgment that TI account for and pay to Far North Patents all damages to and costs incurred by Far North Patents because of TI's infringing activities and other conduct complained of herein, including an award of all increased damages to which Far North Patents is entitled under 35 U.S.C. § 284;

d. That Far North Patents be granted pre-judgment and post-judgment interest on the damages caused by TI's infringing activities and other conduct complained of herein;

e. That this Court declare this an exceptional case and award Far North Patents its reasonable attorney's fees and costs in accordance with 35 U.S.C. § 285; and

f. That Far North Patents be granted such other and further relief as the Court may deem just and proper under the circumstances.

Dated: December 26, 2019

Respectfully submitted,

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