Agenda

IEEE 802.3 Overview

IEEE 802.3 Ethernet Physical Layers
Rate, distance, media

IEEE 802.3 Ethernet emerging technologies
New physical layers, new technologies

Conclusion
Agenda

IEEE 802.3 Overview

IEEE 802.3 Ethernet Physical Layers
Rate, distance, media

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Conclusion
IEEE Std 802.3 Frame format

Size (Octets)

7
1
6
6
2
4

Preamble
SFD
DA
SA
Length/Type
MAC
Client Data
PAD
FCS
Extension

Key:
SFD – Start frame delimiter
DA – Destination address
SA – Source address
MAC – Medium access control
FCS – Frame check sequence

46 to 1500
or 1504
or 1982

Frame
Packet

IEEE 802.3 Overview (Version 1.0 - January 2010)
IEEE Std 802.3 layer diagram
1Mb/s and 10Mb/s

OSI Reference model layers

- Application
- Presentation
- Session
- Transport
- Network
- Data link
- Physical

Higher layers

- LLC or other MAC client

MAC layers

- MAC control
- MAC
- PLS

Physical layers

- PMA
- Medium

Key:
- LLC – Logical link control
- MAC – Medium access control
- PLS – Physical layer signalling
- AUI – Attachment unit interface
- MAU – Medium attachment unit
- PMA – Physical medium attachment
- MDI – Media dependent interface
IEEE Std 802.3 layer diagram
100Mb/s and above

Key:
LLC – Logical link control
MAC – Medium access control
RS – Reconciliation sublayer
xMII – Medium independent interface
PHY – Physical layer device
PCS – Physical coding sublayer
PMA – Physical medium attachment
PMD – Physical medium dependant
MDI – Media dependant interface

xMII:
MII – 100Mb/s Medium independent interface
GMII – 1 Gb/s Medium independent interface
XGMII – 10 Gb/s Medium independent interface
Agenda

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New physical layers, new technologies

Conclusion
## 10Mb/s and 100 Mb/s Ethernet

<table>
<thead>
<tr>
<th>PHY Type</th>
<th>Data rate</th>
<th>Distance</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE Std 802.3-1985 Ethernet MAC, 10BASE5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10BASE5</td>
<td>10Mb/s</td>
<td>500m</td>
<td>Coaxial</td>
</tr>
<tr>
<td>IEEE Std 802.3c-1985 Repeater, FOIRL</td>
<td></td>
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<tr>
<td>FOIRL</td>
<td>10Mb/s</td>
<td>1km</td>
<td>Two multimode</td>
</tr>
<tr>
<td>IEEE Std 802.3a-1988 10BASE2</td>
<td></td>
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</tr>
<tr>
<td>10BASE2</td>
<td>10Mb/s</td>
<td>185m</td>
<td>Coaxial</td>
</tr>
<tr>
<td>IEEE Std 802.3i-1990 10BASE-T</td>
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<td></td>
</tr>
<tr>
<td>10BASE-T</td>
<td>10Mb/s</td>
<td>100m</td>
<td>Twisted-pair</td>
</tr>
<tr>
<td>IEEE Std 802.3j-1993 10BASE-F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10BASE-FP</td>
<td>10Mb/s</td>
<td>1km</td>
<td>Two multimode</td>
</tr>
<tr>
<td>10BASE-FL</td>
<td>10Mb/s</td>
<td>2km</td>
<td>Two multimode</td>
</tr>
<tr>
<td>10BASE-FB</td>
<td>10Mb/s</td>
<td>2km</td>
<td>Two multimode</td>
</tr>
<tr>
<td>IEEE Std 802.3u-1995 100BASE-T</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100BASE-TX</td>
<td>100Mb/s</td>
<td>100m</td>
<td>2 pair Cat 5</td>
</tr>
<tr>
<td>100BASE-T4</td>
<td>100Mb/s</td>
<td>100m</td>
<td>4 pair Cat 3</td>
</tr>
<tr>
<td>100BASE-FX</td>
<td>100Mb/s</td>
<td>2km</td>
<td>Two multimode</td>
</tr>
<tr>
<td>IEEE Std 802.3x-1997 Full Duplex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IEEE Std 802.3y-1997 100BASE-T2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100BASE-T2</td>
<td>100Mb/s</td>
<td>100m</td>
<td>2 pair Cat 3</td>
</tr>
</tbody>
</table>

### Diagram

- **Rate (b/s)**
  - 10G
  - 100G
  - 100M
  - 10M
  - 1M

- **Distance (m)**
  - 0.1
  - 1
  - 10
  - 100
  - 1000
  - 10000
  - 100000

**Key:**
- Backplane
- Co-axial
- Twin-axial
- Twisted pair
- Multimode Fibre
- Single-mode Fibre
- Voice grade copper
- Point to Multipoint Fibre
IEEE 802.3 Overview (Version 1.0 - January 2010)

Topology evolution

IEEE Std 802.i-1990 10BASE-T
IEEE Std 802.3j-1993 10BASE-F

IEEE Std 802.3u-1995 100BASE-T
IEEE Std 802.3x-1997 Full Duplex
TIA/EIA 568:1991 Structured building wiring
ISO/IEC 11801:1995 Structured building wiring

Key:
- Collision domain
- 10BASE2/10BASE5
- 10BASE-T link
- 10BASE-F link
- 100BASE-F link
### 1Gb/s and 10 Gb/s Ethernet

<table>
<thead>
<tr>
<th>PHY Type</th>
<th>Data rate</th>
<th>Distance</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IEEE Std 802.3z-1998 1 Gb/s Operation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000BASE-SX</td>
<td>1Gb/s</td>
<td>220m</td>
<td>Two multimode fibres</td>
</tr>
<tr>
<td></td>
<td></td>
<td>550m</td>
<td></td>
</tr>
<tr>
<td>1000BASE-LX</td>
<td>1Gb/s</td>
<td>5Km</td>
<td>Two single-mode Two</td>
</tr>
<tr>
<td></td>
<td></td>
<td>550m</td>
<td>multimode</td>
</tr>
<tr>
<td>1000BASE-CX</td>
<td>1Gb/s</td>
<td>25m</td>
<td>Copper cable assembly</td>
</tr>
<tr>
<td><strong>IEEE Std 802.3ab-1999, 1000BASE-T</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000BASE-T</td>
<td>1Gb/s</td>
<td>100m</td>
<td>Twisted-pair</td>
</tr>
<tr>
<td><strong>IEEE Std 802.3ad-2000 Link Aggregation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>IEEE Std 802.3ae-2002 10 Gb/s Operation</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>10GBASE-SR/W</td>
<td>10Gb/s</td>
<td>33m</td>
<td>Two multimode</td>
</tr>
<tr>
<td></td>
<td></td>
<td>300m</td>
<td></td>
</tr>
<tr>
<td>10GBASE-LX4</td>
<td>10Gb/s</td>
<td>10Km</td>
<td>Two single-mode Two</td>
</tr>
<tr>
<td></td>
<td></td>
<td>300m</td>
<td>multimode</td>
</tr>
<tr>
<td>10GBASE-LR/W</td>
<td>10Gb/s</td>
<td>10Km</td>
<td>Two single-mode</td>
</tr>
<tr>
<td>10GBASE-ER/W</td>
<td>10Gb/s</td>
<td>40Km</td>
<td>Two single-mode</td>
</tr>
</tbody>
</table>

**Key:**
- Backplane
- Co-axial
- Twin-axial
- Twisted pair
- Multimode Fibre
- Single-mode Fibre
- Voice grade copper
- Point to Multipoint Fibre
# Ethernet in the First Mile

## PHY Type Data rate Distance Media

<table>
<thead>
<tr>
<th>PHY Type</th>
<th>Data rate</th>
<th>Distance</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE Std 802.3ah-2004 Ethernet in the First Mile</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100BASE-LX10</td>
<td>100Mb/s</td>
<td>10Km</td>
<td>Two single-mode</td>
</tr>
<tr>
<td>100BASE-BX10</td>
<td>100Mb/s</td>
<td>10Km</td>
<td>One single-mode</td>
</tr>
<tr>
<td>1000BASE-LX10</td>
<td>1000Mb/s</td>
<td>10Km 550m</td>
<td>Two single-mode Two multimode</td>
</tr>
<tr>
<td>1000BASE-BX10</td>
<td>1000Mb/s</td>
<td>10Km</td>
<td>One single-mode</td>
</tr>
<tr>
<td>1000BASE-PX10</td>
<td>1000Mb/s</td>
<td>10Km</td>
<td>One single-mode Point to Multipoint</td>
</tr>
<tr>
<td>1000BASE-PX20</td>
<td>1000Mb/s</td>
<td>20Km</td>
<td></td>
</tr>
<tr>
<td>10PASS-TS</td>
<td>10Mb/s*</td>
<td>750m*</td>
<td>Voice grade copper</td>
</tr>
<tr>
<td>2BASE-TL</td>
<td>2Mb/s*</td>
<td>2Km*</td>
<td>Voice grade copper</td>
</tr>
</tbody>
</table>

* Nominal speed and reach

---

**Key:**
- Backplane
- Co-axial
- Twin-axial
- Twisted pair
- Multimode Fibre
- Single-mode Fibre
- Voice grade copper
- Point to Multipoint Fibre

---

IEEE 802.3 Overview (Version 1.0 - January 2010)
# 10 Gb/s PHYs, Backplane Ethernet

<table>
<thead>
<tr>
<th>PHY Type</th>
<th>Data rate</th>
<th>Distance</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE Std 802.3ak-2004, 10GBASE-CX4</td>
<td>10Gb/s</td>
<td>15m</td>
<td>Copper cable assembly</td>
</tr>
<tr>
<td>10GBASE-CX4</td>
<td>10Gb/s</td>
<td>15m</td>
<td>Copper cable assembly</td>
</tr>
<tr>
<td>IEEE Std 802.3an-2006, 10GBASE-T</td>
<td>10Gb/s</td>
<td>100m</td>
<td>Twisted-pair</td>
</tr>
<tr>
<td>10GBASE-T</td>
<td>10Gb/s</td>
<td>100m</td>
<td>Twisted-pair</td>
</tr>
<tr>
<td>IEEE Std 802.3ap-2007, Electrical Backplanes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000BASE-KX</td>
<td>1000Mb/s</td>
<td>1m</td>
<td>Backplane</td>
</tr>
<tr>
<td>10GBASE-KX4</td>
<td>10Gb/s</td>
<td>1m</td>
<td>Backplane</td>
</tr>
<tr>
<td>10GBASE-KR</td>
<td>10Gb/s</td>
<td>1m</td>
<td>Backplane</td>
</tr>
<tr>
<td>IEEE Std 802.3aq-2006, 10GBASE-LRM</td>
<td></td>
<td></td>
<td>Two multimode</td>
</tr>
<tr>
<td>10GBASE-LRM</td>
<td>10Gb/s</td>
<td>100m</td>
<td>Two multimode</td>
</tr>
</tbody>
</table>

Key:
- Backplane
- Co-axial
- Twin-axial
- Twisted pair
- Multimode Fibre
- Single-mode Fibre
- Voice grade copper
- Point to Multipoint Fibre
IEEE Std 802.3as-2006 Frame Extension

- Drivers
  - IEEE Std 802.1ad Provider Bridging
    - Tag in Tag
  - IEEE Std 802.1AE MAC Security
    - Cipher block

- Approach
  - Minimal changes
    - Provide for envelope round frame
  - No expansion of MAC Client Data
    - Jumbo frames not supported

- Frame sizes supported
  - 1518 decimal – basic frames
  - 1522 decimal – Q-tagged frames
  - 2000 decimal – envelope frames

Note 1: Envelope prefix + suffix ≤ 482
Agenda

IEEE 802.3 Overview

IEEE 802.3 Ethernet Physical Layers
Rate, distance, media

IEEE 802.3 Ethernet emerging technologies
New physical layers, new technologies

Conclusion
IEEE 802.3 Ethernet emerging technologies

- Demand for increased bandwidth
  - By connected devices
  - By devices aggregating these devices

- Continuing evolution of Ethernet
  - DTE Power via MDI
  - Energy-efficient Ethernet
  - Mapping to OTN

- Convergence around Ethernet
  - Data Centre Bridging (e.g. FCoE, iWARP)
  - Audio/Video Bridging
IEEE Std 802.3 Ethernet Passive Optical Network (EPON) Architecture

- First mile (subscriber access) technology
  - Point to multipoint fibre media
IEEE Std 802.3 Ethernet Passive Optical Network (EPON) Architecture
1Gb/s Passive Optical Networks already supported
- Included in IEEE Std 802.3ah-2004 Ethernet in First Mile
- 1 Gb/s downstream and upstream

Particularly successful in APR
- Competing standards impediment to wider PONs adoption
  - Both IEEE EPONs and ITU specified GPONs

Bandwidth demands increasing
- IPTV, VoD

IEEE Std 802.3av-2009 10Gb/s EPON
- Symmetric 10 Gb/s downstream and upstream
- Asymmetric 10 Gb/s downstream, 1Gb/s upstream
## IEEE Std 802.3av-2009 10Gb/s EPON Ethernet PHY Types

<table>
<thead>
<tr>
<th>PHY Type</th>
<th>Data rate</th>
<th>Split ratio</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/1GBASE-PRX1</td>
<td>1Gb/s</td>
<td>10Gb/s</td>
<td>1:16</td>
</tr>
<tr>
<td>10/1GBASE-PRX2</td>
<td>1Gb/s</td>
<td>10Gb/s</td>
<td>1:16</td>
</tr>
<tr>
<td>10/1GBASE-PRX3</td>
<td>1Gb/s</td>
<td>10Gb/s</td>
<td>1:32</td>
</tr>
<tr>
<td>10GBASE-PR1</td>
<td>10Gb/s</td>
<td>10Gb/s</td>
<td>1:16</td>
</tr>
<tr>
<td>10GBASE-PR2</td>
<td>10Gb/s</td>
<td>10Gb/s</td>
<td>1:32</td>
</tr>
<tr>
<td>10GBASE-PR3</td>
<td>10Gb/s</td>
<td>10Gb/s</td>
<td>1:32</td>
</tr>
</tbody>
</table>

### Diagram

- **Rate (b/s)**
  - 100G
  - 10G
  - 1000M
  - 100M
  - 10M
  - 1M

- **Distance (m)**
  - 0.1
  - 1
  - 10
  - 10^2
  - 10^3
  - 10^4
  - 10^5

### Key:
- -  Backplane
- -  Co-axial
- -  Twin-axial
- -  Twisted pair
- -  Multimode Fibre
- -  Single-mode Fibre
- -  Voice grade copper
- -  Point to Multipoint Fibre
IEEE P802.3ba 40Gb/s and 100Gb/s Ethernet Interface(s)

**XLGMII / CGMII**
- 40 / 100 Gigabit Media Independent Interface
- TX and RX data paths
- 64 data (8 ‘lanes’ of 8 bits), 8 Control, 1 Clock, 625Mhz @ 40Gb/s, 1.5625GHz @ 100Gb/s
- Logical interface (supports system on a chip)

**XLAUI / CAUI**
- 40 / 100 Gb/s Attachment Unit Interface
- 4 (XLAUI) / 10 (CAUI) lanes of 10Gb/s, 64B/66B encoded, 10.3125GBaud/s
- To support 25cm FR- 4 PCB traces
- Total: XLAUI 16 pins; CAUI 40 pins

**XLPPI / CPPI**
- 40 / 100 Gb/s Parallel Physical Interface
- 40GBASE-SR4 or 100GBASE-SR10
- Encoding the same as XLAUI/CAUI
- No retiming (short distance)

PCS = Physical Coding Sublayer
PMA = Physical Medium Attachment
PMD = Physical Medium Dependent

---

IEEE 802.3 Overview (Version 1.0 - January 2010)
## IEEE P802.3ba 40Gb/s and 100Gb/s Ethernet PHY types

<table>
<thead>
<tr>
<th>PHY Type</th>
<th>Data rate</th>
<th>Distance</th>
<th>Media</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>100GBASE-ER4</td>
<td>100Gb/s</td>
<td>40km</td>
<td>Single Mode Fibre</td>
<td>4 x 25Gb/s (28.78125GBaud) 1310nm DWDM (5nm), SOA</td>
</tr>
<tr>
<td>100GBASE-LR4</td>
<td>100Gb/s</td>
<td>10km</td>
<td></td>
<td>4 x 25Gb/s (28.78125GBaud) 1310nm DWDM (5nm)</td>
</tr>
<tr>
<td>40GBASE-LR4</td>
<td>40Gb/s</td>
<td>10km</td>
<td></td>
<td>4 x 10Gb/s (10.3125GBaud) 1310nm CWDM (20nm)</td>
</tr>
<tr>
<td>100GBASE-SR10</td>
<td>100Gb/s</td>
<td>100m</td>
<td>OM3 multimode fibre</td>
<td>10 x 10Gb/s (10.3125GBaud) 850nm, 10 pairs of fibres</td>
</tr>
<tr>
<td>40GBASE-SR4</td>
<td>40Gb/s</td>
<td>100m</td>
<td></td>
<td>4 x 10Gb/s (10.3125GBaud) 850nm, 4 pairs of fibres</td>
</tr>
<tr>
<td>100GBASE-CR10</td>
<td>100Gb/s</td>
<td>7m</td>
<td>Copper cable assembly</td>
<td>10 x 10Gb/s (10.3125GBaud) 10 differential pairs</td>
</tr>
<tr>
<td>40GBASE-CR4</td>
<td>40Gb/s</td>
<td>7m</td>
<td></td>
<td>4 x 10Gb/s (10.3125GBaud) 4 differential pairs</td>
</tr>
<tr>
<td>40GBASE-KR4</td>
<td>40Gb/s</td>
<td>1m</td>
<td>Backplane</td>
<td>4 x 10Gb/s (10.3125GBaud) 4 10GBASE-KR channels</td>
</tr>
</tbody>
</table>
IEEE P802.3ba 40Gb/s and 100Gb/s Ethernet PHY Types under development

<table>
<thead>
<tr>
<th>PHY Type</th>
<th>Data rate</th>
<th>Distance</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>100BASE-ER4</td>
<td>100Gb/s</td>
<td>40km</td>
<td>Dual Single-mode fibres</td>
</tr>
<tr>
<td>100BASE-LR4</td>
<td>100Gb/s</td>
<td>10km</td>
<td>Single-mode fibres</td>
</tr>
<tr>
<td>40GBASE-LR4</td>
<td>40Gb/s</td>
<td></td>
<td>Multiple multimode fibres</td>
</tr>
<tr>
<td>100BASE-SR10</td>
<td>100Gb/s</td>
<td>100m</td>
<td>Multiple multimode fibres</td>
</tr>
<tr>
<td>40GBASE-SR4</td>
<td>40Gb/s</td>
<td>125m</td>
<td>Copper cable assembly</td>
</tr>
<tr>
<td>100BASE-CR10</td>
<td>100Gb/s</td>
<td>7m</td>
<td>Copper cable assembly</td>
</tr>
<tr>
<td>40BASE-CR4</td>
<td>40Gb/s</td>
<td></td>
<td>Backplane</td>
</tr>
<tr>
<td>40BASE-KR4</td>
<td>40Gb/s</td>
<td>1m</td>
<td>Backplane</td>
</tr>
</tbody>
</table>

Key:
- Backplane
- Co-axial
- Twin-axial
- Twisted pair
- Single-mode Fibre
- Multimode Fibre
- Voice grade copper
- Point to Multipoint Fibre

Rate (b/s)

Distance (m)
IEEE Std 802.3at-2009 DTE Power Enhancement Overview

- Amendment to IEEE Std 802.3af DTE Power via MDI
  - Interoperation with existing equipment
    - Higher power source will supply existing devices
- Modification to existing standard so need to identify PSE
  - ‘Type 1’ - Existing IEEE Std 802.3af PSEs and PDs
  - ‘Type 2’ – New higher power capacity PSEs and PDs
- Cabling
  - 100 meters of ISO/IEC 11801-1995 Class D or better
    - Loop resistance less that 25 Ohms
  - Met by Category 5 or better
    - Under worst case conditions requires a 10C reduction in maximum ambient operating temperature of the cable.
- Supports a 25.5 Watts at PD
IEEE P802.3az Energy-efficient Ethernet
Idle operation overview

- Low power mode:
  - Updates receiver parameters, timing information and filter coefficients
  - Signal to receive
    - System to exit low power state

- Normal operation:

Packet | PGP | Packet | PGP | Sleep | Refresh | Refresh | Wake | Packet | PGP | Packet

IEEE 802.3 Overview (Version 1.0 - January 2010)
IEEE P802.3az Energy-efficient Ethernet System energy savings
IEEE P802.3az Energy-efficient Ethernet
System energy savings, TX queue empty
IEEE 802.3 project status

IEEE 802.3 40Gb/s
Single Mode PHY
IEEE 802.3
Timestamp support SG
IEEE P802.3.1
Ethernet SNMP MIBs
IEEE Std 802.3bc-2009
Ethernet TLVs
IEEE 802.3bb PAUSE timing
IEEE 802.3ba 40Gb/s &
100Gb/s Ethernet
IEEE P802.3az Energy-
efficient Ethernet
IEEE Std 802.1AX Link
Aggregation (IEEE 802.3ax)
IEEE Std 802.3av-2009
10Gb/s PHY for EPON
IEEE Std 802.3at-2009
DTE Power enhancements

SG – Study Group formation
TF – Task Force review
WG – Working Group ballot
SB – Sponsor Ballot
STD – Standards Board
approval
Agenda

IEEE 802.3 Overview

IEEE 802.3 Ethernet Physical Layers
Rate, distance, media

IEEE 802.3 Ethernet emerging technologies
New physical layers, new technologies

Conclusion
Conclusions

- Ethernet is the ubiquitous wired connectivity
  - < 0.01m to 1,000s of kilometres
  - 10Mb/s to 10Gb/s
    - Link Aggregation
    - Backplane to fibre (and everything in between)
- New speeds, media, features and applications reinforce this
  - 40Gb/s and 100Gb/s
  - Energy-efficient Ethernet
- Continued convergence on Ethernet
  - Data Centre Bridging
  - Audio/Video Bridging
IEEE 802.3 Standards

- IEEE Std 802.3™-2008 Ethernet Access Method and Physical Layer Specifications*
  - IEEE Std 802.3av™-2009 10Gb/s EPON
  - IEEE Std 802.3bc™-2009 Ethernet TLVs
  - IEEE Std 802.3at™-2009 DTE Power Enhancements

* Available through Get IEEE 802
  http://standards.ieee.org/getieee802/802.3.html
# Revision history

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Comment</th>
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<tr>
<td>1.0</td>
<td>20(^\text{th}) Jan 2010</td>
<td>Initial version based on IEEE Standards Education Committee GlobeCom 2009 Workshop presentation.</td>
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