IEEE-1588™ Many Applications, Different Requirements

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AGENDA

- **IEEE-1588™ Status**
- **Applications of Interest for 1588**
- **IEEE-1588 Standard's work**
  - **Transparent Clock**
  - **Short Frame**
  - **Fault Tolerant Clocks**
  - **Security**
- **Summary**

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IEEE-1588 Status

- **IEEE-1588 – Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems**
  - **Defines a Precision Time Protocol (PTP) designed to synchronize real-time clocks in a distributed system**
  - **Intended for Local Area Networks using multicast communications (including Ethernet)**
  - **IEEE-1588 designed to work within a building or factory**
    - **Intended typically for industrial automation and test and measurement systems (e.g. synchronized printing presses)**
  - **Targeted accuracy of microsecond to sub-microsecond**
  - **Approved in September 2002 and published November 2002**
  - **Available from the IEEE-1588 web site**

    http://ieee1588.nist.gov

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IEEE-1588 Status, Cont'd

- **The PAR (Project Authorization Request) was approved in March 2005**
  - **P1588 – Precise Networked Clock Synchronization Working Group was formed**
    - **Resolution of known errors**
    - **Conformance enhancements**
    - **Enhancements to address new applications (including telecom)**
- **P1588 is meeting twice monthly via conference calls**
- **Face-to-face meeting in June at NIST in Gaithersburg**
- **IEEE 1588 Workshop in October at NIST in Gaithersburg**

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Application of Interest

- **Industrial Automation**
- **Test and Measurement:**
  - **RF Spectrum correlation, I/Q**
  - **Signal Correlation, Stimulus-Response, and High-Speed Logic**
  - **Low Frequency Devices**
- **Telecom**
- **Residential Ethernet (AVB group at IEEE 802.1)**
- **Military**
- **Power Industry**
- **Measurement and Control**
  - **Process Control Applications**
- **Automotive (On-Board Control)**

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Industrial Automation

- **Several different applications**
  - **General Motion Control**
    - **High-speed Printing can be very demanding regarding accuracy**
  - **Robotics**
    - **Load Sharing**
    - **Process Relative Motion**
- **Controlled Network**
- **Synchronization accuracy from microseconds to milliseconds**

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RoboTeam in Action: Load Sharing

Courtesy of Kuka Robotics Corp.

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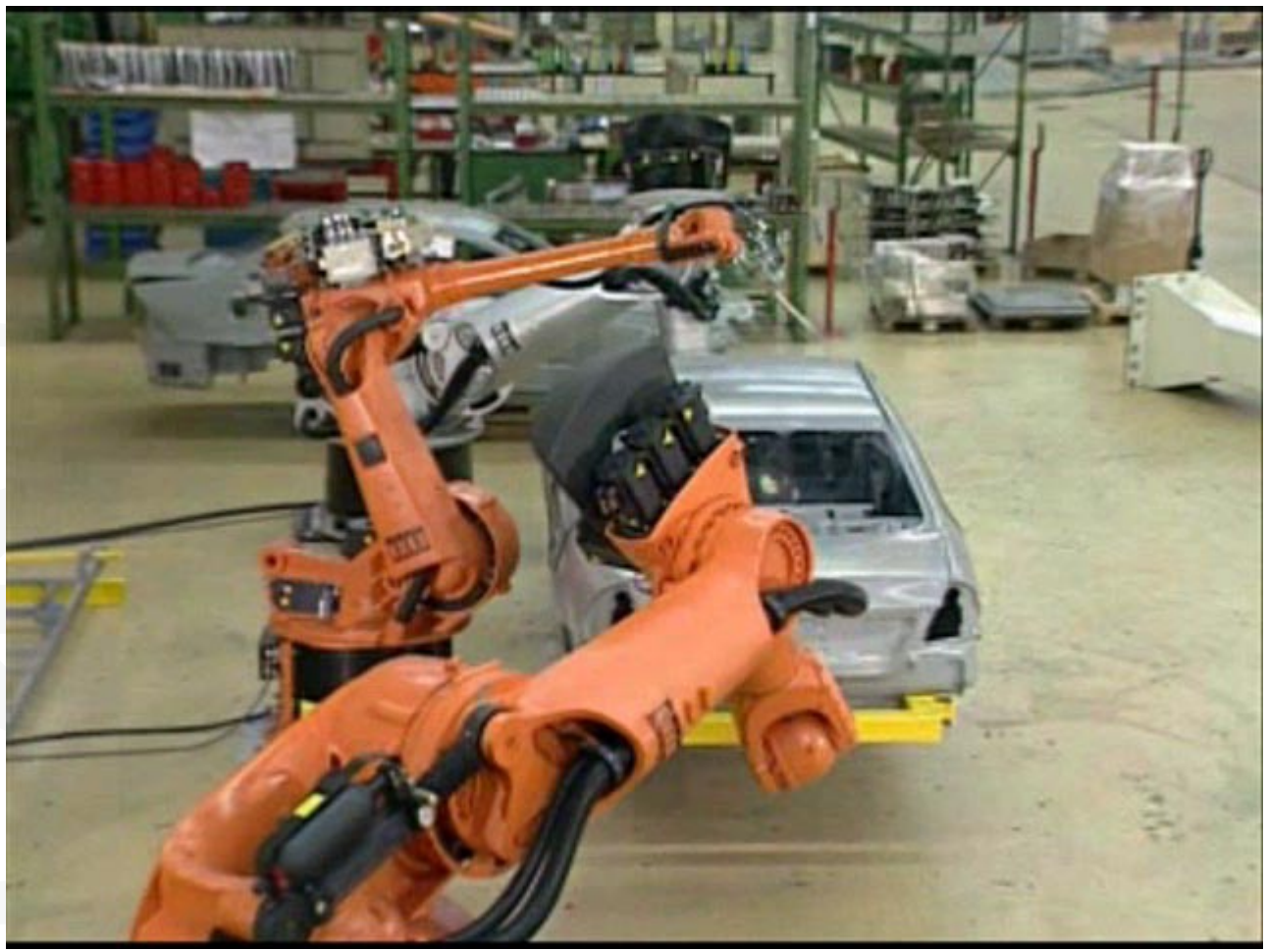
RoboTeam in Action: Process Relative Motion

Courtesy of Kuka Robotics Corp.



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Test and Measurement

- **Different applications**
  - **Complex high-performance RF instrumentation**
  - **Signal Correlation, stimulus response**
- **Trend is to move from GPIB (IEEE-488) bus to connect instruments to a network connected modular systems**
- **Controlled network**
- **Synchronization accuracy from microseconds to milliseconds**

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Telecom

- **Potential Applications**
  - **Wireless Backhaul**
  - **Circuit Emulation Services (CES)**
  - **Passive Optical Network (PON)**
- **Uncontrolled Network**
- **Synchronization Requirements**
  - **GSM, WCDMA, and CDMA2000 require frequency accuracy of 0.05 ppm at air interface**
  - **CDMA2000 requires time synchronization at +/- 3µs (+/-10µs worst case)**
  - **WCDMA TDD mode requires 2.5µs time accuracy between neighboring base stations (i.e. +/- 1.25µsof UTC)**
  - **CES applications requirements defined in G.8261 (formerly G.pactiming)**

    Maximum wander of 4.3µs (2048Kbits/s interface) and 4.5µs (1544kbits/s interface) for the CES Deployment Case 1

    Maximum wander of 16µs for the CES Deployment Case 2

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Residential Ethernet (AVB group at IEEE 802.1)

- **Home entertainment applications for voice, video, interactive applications and musical equipment**
- **Trend is to use Ethernet to connect home entertainment equipment**
  - **For example, playing different audio tracks in each room, or playing same track in multiple room**
- **Network model of 7 Switches**
- **Synchronization accuracy**
  - **1us maximum wander from the grand-master station**

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Military

- **Potential Applications**
  - **Tests**
  - **Operational Systems**
- **High-precision accuracy over wide geographical areas**
- **Synchronization accuracy can be fraction of microseconds**

  Phased Array Radar test needs 10-50 picoseconds

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1588 Standard's Work – Major Topics

- **Transparent Clock**
- **Short Frame**
- **Fault Tolerant Clocks**
- **Security**

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Transparent Clock vs. Boundary Clock

- **Existing standard specifies Boundary Clock (BC) mechanism**
  - **BC does not propagate Sync, Follow_Up, Delay_Req, or Delay_Resp messages**
  - **BC mechanism suitable for topology with small number of switches**
  - **Cascading BCs introduce the cascade effect**
    - **BC distributes timing based on the its local clock**
    - **Each clock depends on the quality of all preceding clocks**
- **Version 2 of 1588 specifies Transparent Clock (TC) mechanism**
  - **Two types of transparent clock - End to End (E2E) and Point to Point (P2P)**
  - **TC mechanism is suitable for topology with either small or large number of switches**
  - **Cascade effect in cascading TCs is much better than cascading BCs**
    - **Each clock does not depend on the quality of the preceding clocks**

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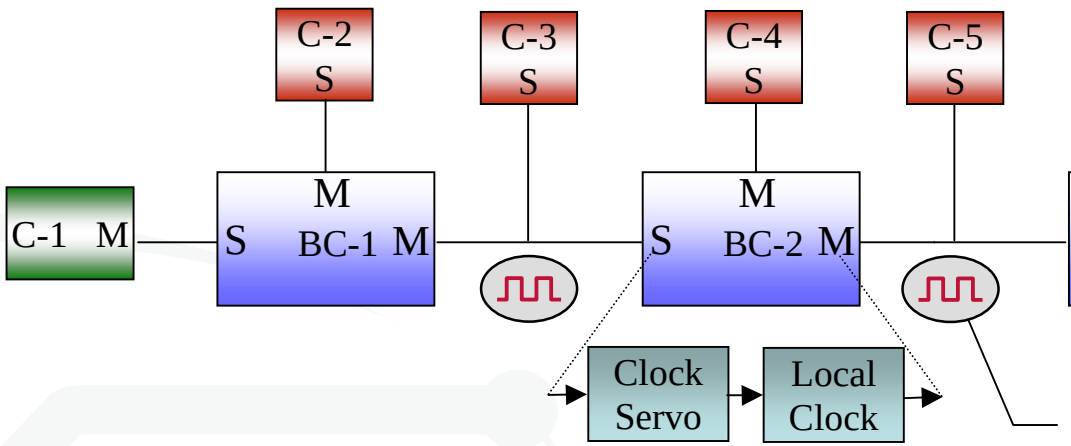
Boundary Clock



- ✓ **Clock in the cascade devices is affected by**
  - **The local clock of the predecessor**
  - **Servo error and quantization errors**

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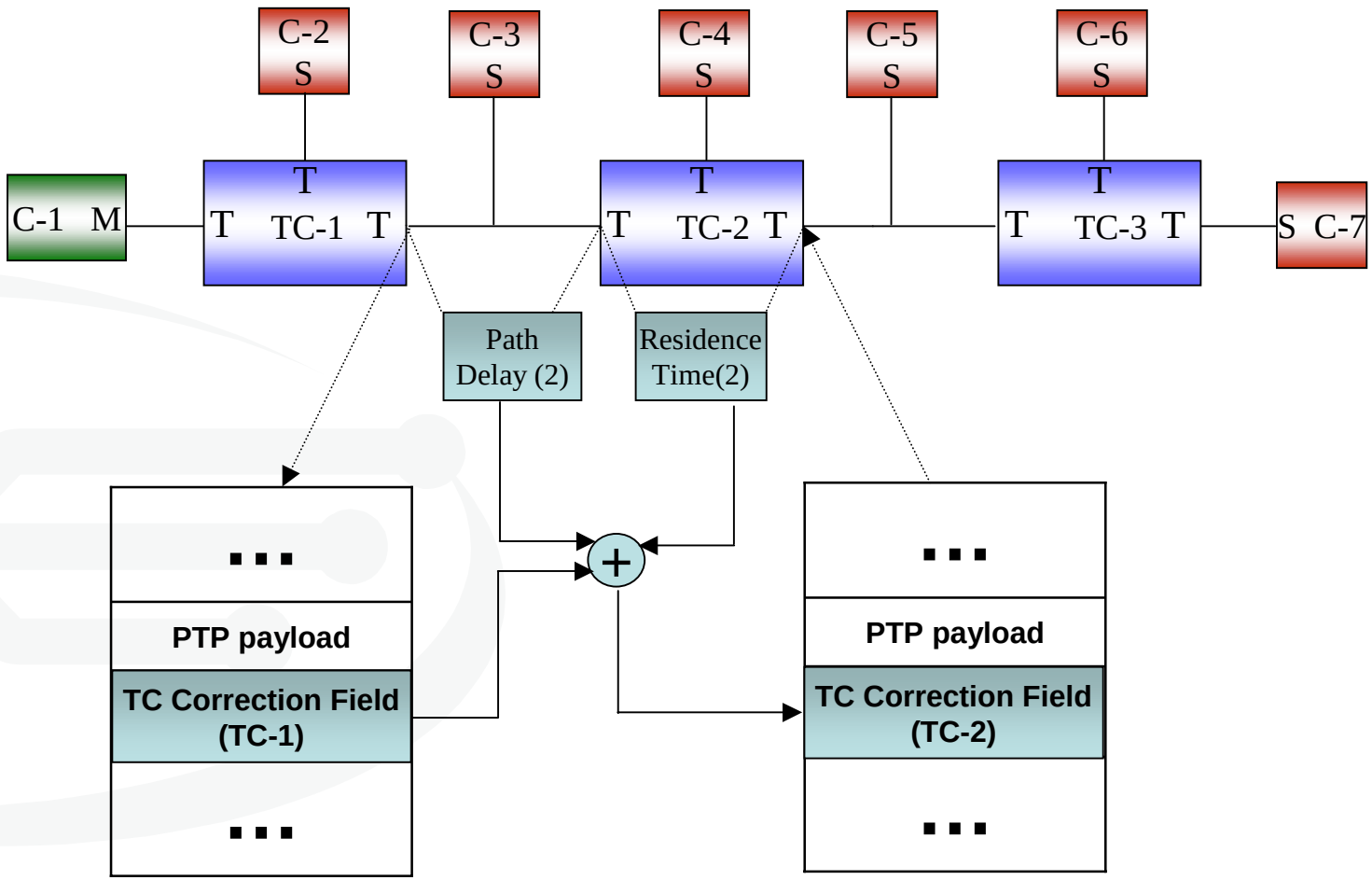
Transparent Clock



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Short Frame Format

- **Variable Length Unified Frames Format**
  - **Allows compatibility with 1588 version 1 hardware**
  - **Addresses IPV4, IPV6 and Layer 2 (Ethernet)**
- **New Announce message to be used for Best Master Clock algorithm**
- **Variable Length Unified Frames Messages**
  - **Sync Message**
  - **Follow-up Message**
  - **Delay_Request Message**
  - **Delay_Response Message**
  - **Pdelay_Request (for Transparent Clock)**
  - **Pdelay_Response (for Transparent Clock)**
  - **Pdelay_Response_followup (for Transparent Clock)**
- **It allows shorter sync_intervals**

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Fault Tolerant Clocks

- **Fault Tolerant Clock goals:**
  - **The fault of any single network element can not cause slaves to experience a sudden phase change**
  - **A faulty grand master should be detected and replaced rapidly by another grand master**
  - **Switching from one grand master to another should not result in a significant phase step at the slaves**
  - **Fault tolerant clocks must work in networks with simple slaves that uses inexpensive oscillators and have no processors**
  - **Fault tolerant clocks must work in networks with ordinary switches and routers**

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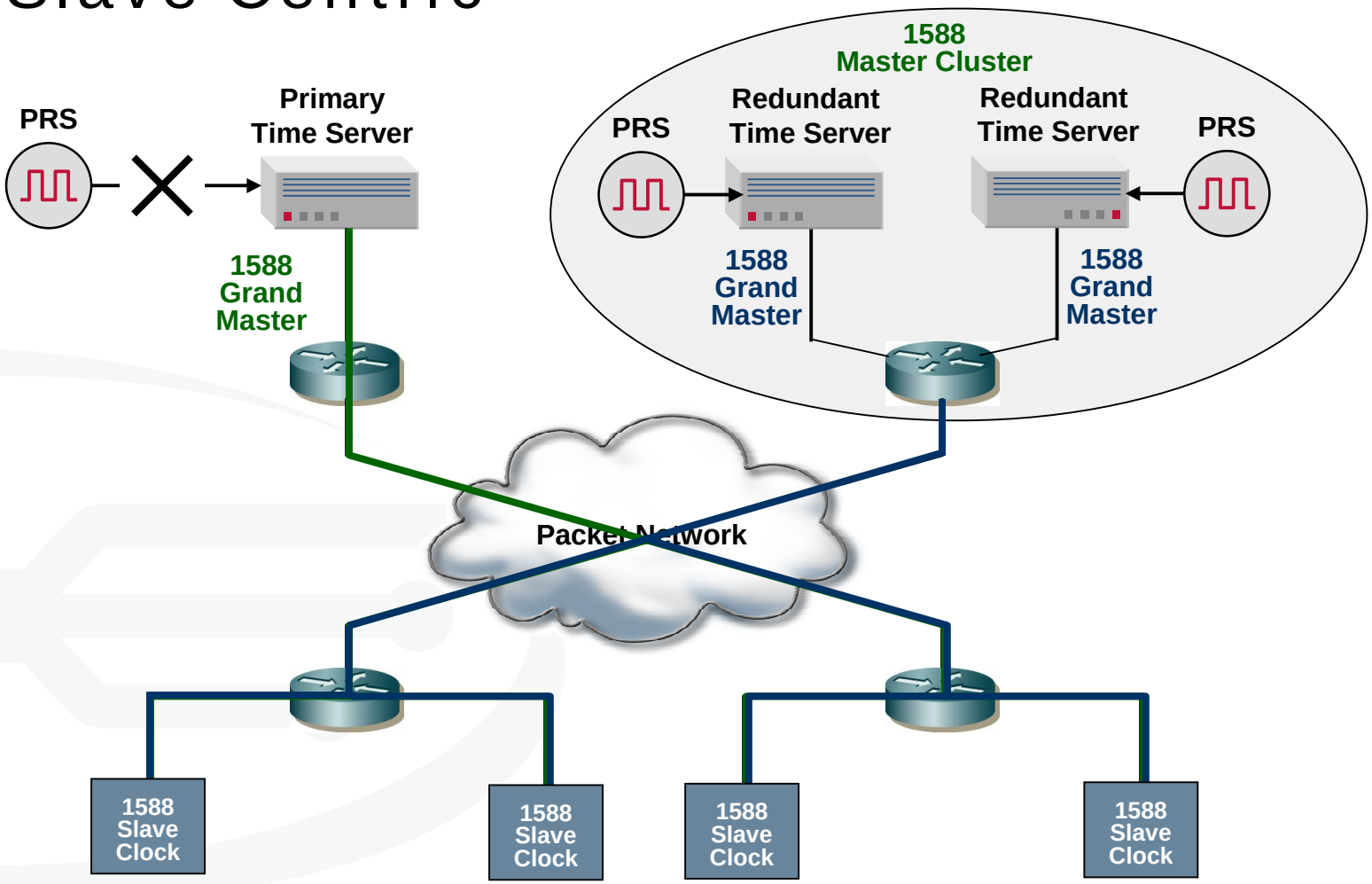
IEEE-1588 Fault Tolerant Clocks – Slave Centric



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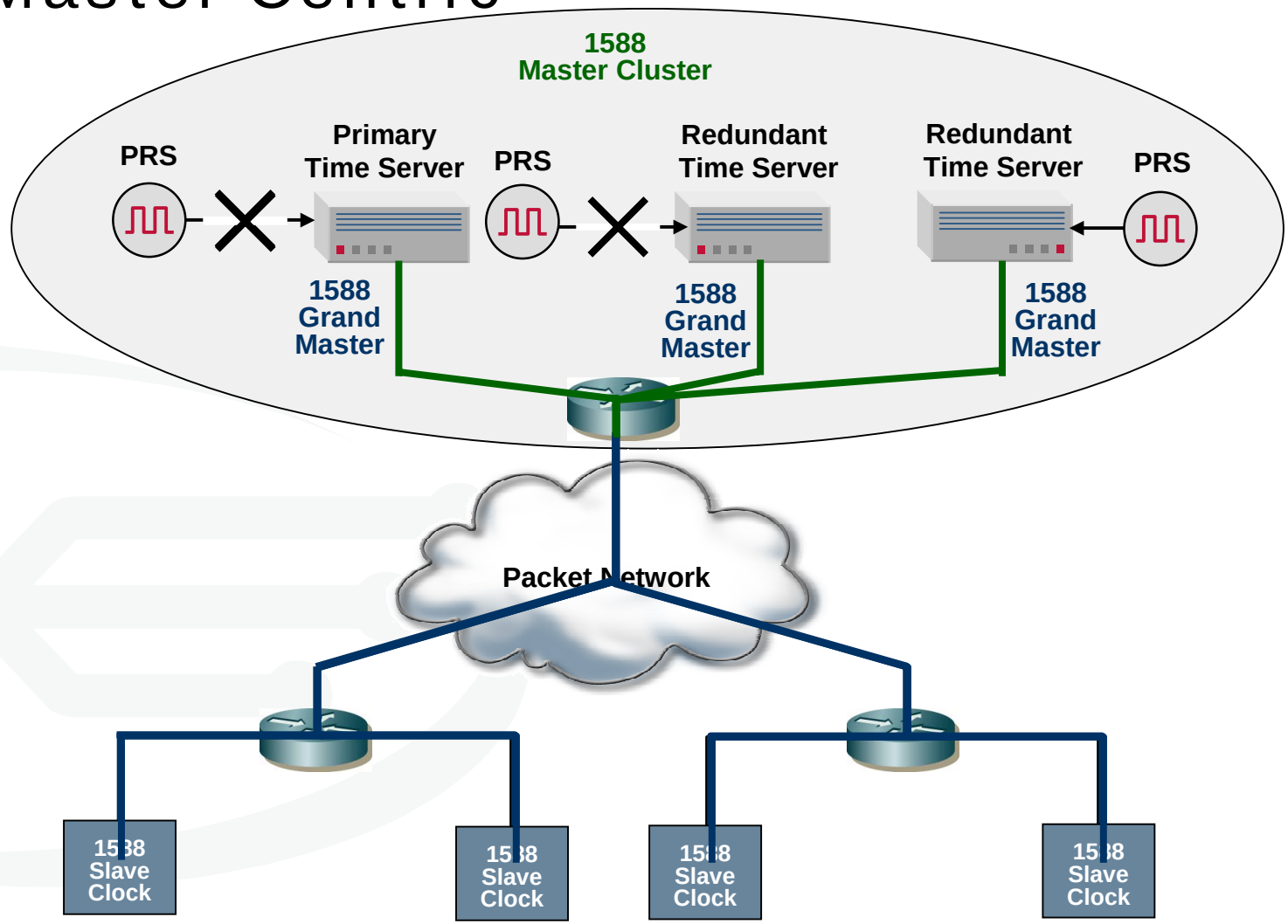
IEEE-1588 Fault Tolerant Clocks – Master Centric



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Security

- **Initial work on Security**
  - **Message extension fields to be used as an option for security**
  - **Encryption of messages does not seem to be required**
  - **Integrity protection and authentication between PTP-Ports seems to be enough for the different applications**
  - **Secure Administration of PTP-Ports**
  - **Goal is to reuse suitable standardized algorithms for security**

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Summary

- **Work on Version 2 of the IEEE1588 is progressing well**
- **Several Industries with different applications are participating in developing the second generation of IEEE1588**
  - **Compromises need to be taken to progress the work**
- **The work in IEEE1588 to support Telecom is progressing**
  - **Good work progress on Short Frame Format**
  - **Fault Tolerant work is on-going**
  - **Still several issues that need work**
    - **Issues must be resolved in a timely matter**
    - **Adding complex functionality to the standard should be avoided as much as possible**

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References

- **Informal IEEE1588 Website: http://ieee1588.nist.gov/**
- **Formal IEEE 1588 Website: http://grouper.ieee.org/groups/1588/**
- **John C. Eidson, Measurement, Control and Communication Using IEEE 1588, Springer, ISBN: 1-84628-250-0**
- **Matthias Wenk, Clock Synchronization based on Transparent Clock Approach, Proceedings of the 2005 IEEE 1588 Conference**
- **Stephan Schüeler, IEEE1588 Security Extensions: Requirements and proposed solutions, Proceedings of the 2005 IEEE 1588 Conference**
- **Doug Arnold et al., Proposal for Fault Tolerance, IEEE 1588 standard contribution**
- **Sivaram Balasubramanian, John Eidson, Proposal for Variable Length Unified Frames that Preserves Backward Compatibility with Existing Hardware, IEEE 1588 standard contribution**

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