L2 Routing for Control Data Traffic @ Industry

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NEW IDEA
ISIS-SPB for Audio/Video- or Control-Data-Streams

Characteristics of Streams (I):
- Own traffic class for streams (priority tag is used for separation)
  - Audio-Video (AV) streams
    - AV streams high, class A, e.g. default priority 3
    - AV streams low, class B, e.g. default priority 2
  - Control Data (CD) streams
    - CD streams high, class A, e.g. default priority 6
    - CD streams low, class B, e.g. default priority 5
- Unique destination address (using engineered multicast and unicast addresses for streams)
- Unidirectional traffic (no feedback)

continued on next slide
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Characteristics of Streams (II):

- Time sensitive traffic (low latency)
- Fixed transmission period
  - Audio-Video (AV) streams
    - AV streams high, 125µs transmission period
    - AV streams low, 250µs transmission period
  - Control Data (CD) streams
    - CD streams high, one common transmission period per area in range between 31.25µs – 250µs
    - CD streams low, one common transmission period per area in range between 250µs – 1ms
- Typical frame size for streams in the range of 64 to 400 bytes
- Reserved bandwidth for streams
  - Limited number of CD streams and AV streams in a convergent network
- Connectivity p2p or p2m (one talker -> multiple listeners, n2m seldom)
  - Typically a limited number of talkers / listener
- Limited areas (domains, domain boundary)
  - No inter domain communication for Control Data Streams
- ...

Typically a limited number of talkers / listener

Limited areas (domains, domain boundary)

No inter domain communication for Control Data Streams

...
Control Data Streams

Control Data:
- data frames
- specific requirements derived from applications in industrial automation and automotive (e.g. low latency, high reliability)
- often specific characteristics (e.g. periodic small size frames)

Control Data Streams:
- control data is sent as streams
- continuous control data traffic during operation of industrial plant etc.
- similar to AV streams (but higher requirements)
- high reliability necessary
Industrial Communication within one network @ Industry

PLC: Programmable Logic Controller for input/output data
DEV: Device for input/output data (sensor/actuator)

↔ PLC – DEV communication relation
↔ PLC – PLC communication relation
↔ Real time diagnostic streams

Ethernet

Plant Backbone

Synchronization

GPS Clock

Control Level

Field Level

Robotic Cell

Machinery Cell

Motion Control Cell

PLC ↔ Server communication for
- download configuration
- download PLC programs
- download prescriptions
And
- upload production data
- real-time diagnostic data

cell-cell communication area
PLC ↔ PLC
control data traffic
communication

functional area for PLC ↔ DEV
control data traffic
communication
Forwarding path control protocols (RSTP, MSTP, SPB) are required for convergent networks to avoid communication loops for:

- Best effort traffic
- AV Streams (Real time diagnostic data streams)
- ISIS-SPB for streams is used for Control Data traffic

RSTP provides loopfree data tree for:
- Best effort traffic plane
- Audio/Video streams

ISIS-SPB for Control Data traffic

- Physical network plane

Not visible for AV streams

Not visible for ISIS-SPB

Legacy network
Communication Characteristics for Control Data Traffic in Industry

- **Topology**
  - up to 2000 nodes
  - max. 64 hops per ring
  - multiple network segments (join, divide of areas at runtime)

- The relationship between source and destination(s) is already known
  - Derived from industrial application
  - Higher layer protocols (establish connectivity)
  - Planning with engineering tool

- A typical control network is a hierarchical network which consists of
  - A small number of PLCs communicating with a huge number of sensors and actuators (n : m)
  - A huge number of sensors and actuators communicating with a small number of PLCs (m : n)
  - Only the small number of PLC may communicate with each other

- The communication for control data is typically bidirectional (sensor/actuator)
  - Symmetric paths are expected (equal latency for both directions)
  - However, streams are unidirectional → one stream for each direction
Communication Characteristics for Control Data Traffic in Industry

**Dynamics of Topology Changes:**

- **Add new device (sometimes)**
  - Incremental routing for paths to new device
  - New streams – incremental reservation

- **Link failure (very rare)**
  - Caused by mechanical stress (cable, connector)

- **Device failure (very rare)**

- **Lifetime of streams (very long)**
  - hours
  - days
  - years

- **Bandwidth requirements for control data traffic (very stable)**

- **Changes to network segment(s) (sometimes)**
  - triggered by partial changes to production line
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Requirements for Streams:

- **Single path connection**
  - Setup routing at startup
  - Re-routing after link error
  - Re-routing or add routing shall not disturb Control Data stream flows which were not directly affected by the link failure

- **Multi path / redundant path connection**
  - Setup routing at startup
  - No immediate re-routing on link-breaks or bridge failures (redundant transmission, i.e. strict 1+1 protection) → seamless redundancy for high availability
  - Re-routing or add routing shall not disturb Control Data stream flows which were not directly affected
  - Support single and dual/multiple homing
  - Use of maximal disjoint paths

- **Multiple talkers for one stream**
  - Identical streams (e.g. microphone, redundant sensors) generated at different sources at the same time
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- two VLANs – one for primary path, one for secondary path
- separation by VLAN ID in order to support multiple traffic classes with different quality of service within a network
- address learning not required, FDB is set by routing algorithm
- ISIS-SPB used for exchange of link state information
- different routing method (multi-path)
- routing based on customer MAC addresses (= unique multicast MAC addresses)
- no differentiation between customer and backbone networks at field and control level \(\rightarrow\) a convergent network is required
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Requirements on multipath routing: Single homing and dual / multi homing

Assumption: one VLAN for primary path and one VLAN for secondary path

**T talker – dual/multi homing**
**L listener- dual/multi homing**

- all possible paths are usable -

- link disjoint and node disjoint shortest path pair -

- max disjoint shortest path pair -

No bridging supported

might be non-shortest path

primary path
secondary path

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Requirements on multipath routing: Multicast (1:m – one talker, multiple listeners)

T talker – dual/multiple homing
L listener- dual/multiple/single homing

- multicast routing for streams -
- one common stream for multiple listeners -

- multicast routing for streams -
- one common stream for multiple listeners –
- option: duplicate filtering on bridge edge
ports with encapsulation for sequence number
and ID for stream -

one possible solution

primary path
secondary path

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Requirements on multipath routing: Multiple Network Segments (Network Segment Protection)

- multicast routing for streams
- one common stream for multiple listener –
- no single point of failure in whole network (reliable with one failure within whole network) -

T talker – dual/multiple homing
L listener- dual/multiple/single homing

multi-path routing in whole network

network segment
replication on connecting links
bridges with duplicate filtering
bridge port with duplicate filtering

Adantages:
- low bandwidth consumption
- learning allowed

Primary path
Secondary path
Copy of frame from primary or secondary path + tagging on egress port
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Requirements on multipath routing: Multiple Segments

T talker – dual/multiple homing
L listener – dual/multiple/single homing

- multicast routing for streams -
- one common stream for multiple listener –
  - no duplicate filtering -
- no single point of failure in each segment
  (reliable with one failure within each segment) -

Constrains:
- huge bandwidth consumption without duplicate filtering
- no learning (problem with learning)

primary path
secondary path

replication on connecting links

No practical solution

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Requirements on multi path routing: Multiple Talkers with identical streams

T talker – multiple talker, single homing
L listener- dual/multiple/single homing

- multicast routing for streams -
- common identical streams from multiple talkers for multiple listeners -

Identical streams (e.g. microphone) generated at different sources at the same time
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Benefits of SPB (as in 802.1Q):
- ISIS-SPB for information exchange (link state) between bridges
- uses customer MAC address (SPB-V)
- computes shortest paths between bridges (SPB)
- Supports virtualization within a VLAN, specifically per-service pruned multicast trees (SPB-VM, in different ways)
- runs within single VLAN ID (SPB-M)
- loop prevention

IDEA:
Use ISIS-SPB for Audio/Video Streams and Control Data Streams
- Plus some enhancements for streams (e.g. engineered paths, non-shortest paths, protection mechanisms such as 1+1 protection and network segment protection, bandwidth reservation for streams)
- SPB for Streams = subset of SPB (.1aq) + enhancements for streams
Further Questions?