Reservation with Resource Allocation Protocol (RAP) for Time-Sensitive Streams using Asynchronous Traffic Shaper (ATS)

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Overview

This slide deck, as an individual contribution of the editors, discusses how the P802.1Qdd Resource Allocation Protocol (RAP) can support dynamic reservations for streams using the P802.1Qcr Asynchronous Traffic Shaping (ATS).

Leveraging the ATS latency math described in the Annex X of P802.1Qcr/D1.0, this deck shows a stream admission control scheme as an example of how to achieve bounded latency and zero congestion loss for dynamic stream establishment using RAP.

To enable accurate calculation of per-hop delay and buffer requirements on each bridge, e.g. by taking account of clock deviations, the needed information to be carried in the reservation attributes is also investigated.

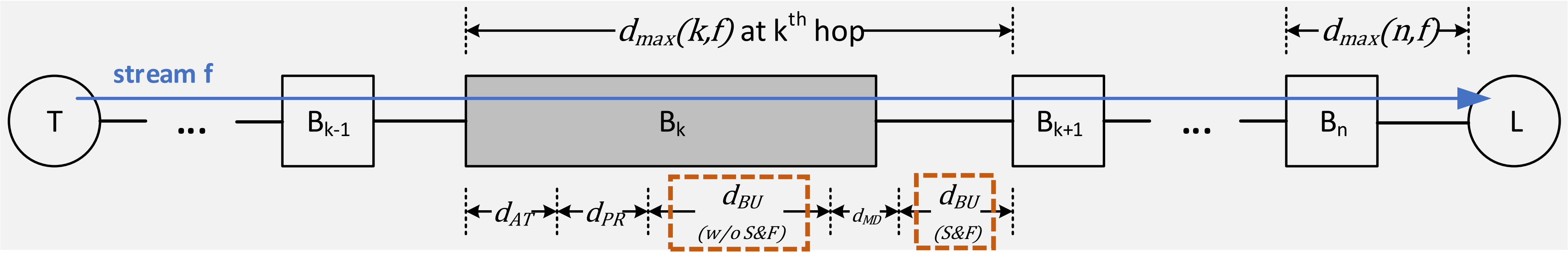
Key Features of ATS

- Asynchronous operation independent of clock synchronization
  - the timing of frames determined based on local clocks
  - taken inter-device clock rate deviations into account for cal. of latency bounds
- Per-stream reshaping combined with per-class queuing (aka. interleaved shaping)
  - eliminating the burstiness cascade effect of per-class shaping (e.g. CBS)
  - end-to-end latency decomposed into topology-independent per-hop latency bound
  - providing protection against babbling idiots through integrated accurate policing
- Traffic characterization using Token Bucket model
  - traffic specification decoupled from the class measurement interval
  - allowing use of arbitrary transmission period for each stream, i.e. per-stream interval
- Applicable for both static and dynamic stream establishment
  - The use of ATS for static cases is analyzed in the paper [1].
  - **This presentation focuses on use of the 802.1Qdd-RAP for dynamic cases.**

[1] J. Specht and S. Samii, "Synthesis of Queue and Priority Assignment for Asynchronous Traffic Shaping in Switched Ethernet," *2017 IEEE Real-Time Systems Symposium (RTSS)*, Paris, 2017, pp. 178-187.

ATS Latency Math in P802.1Qcr/D1.0

The latency decomposition model for ATS described in *Annex X of P802.1Qcr/D1.0*



- **Delay bound at k^th hop for stream f:** $d_{max}(k,f) = d_{AT,max}(k) + d_{PR,max}(k) + \boxed{\boldsymbol{d_{BU,max}(k,f)}} + d_{MD,max}(k)$

- The cal. of the max. buffering delay $\boldsymbol{d_{BU,max}(k,f)}$ uses the detailed information of all streams to be transmitted at B_k.
- The other per-hop delay components are stream independent and can be derived from the bridge parameters.

$$\boxed{d_{BU,max}(k,f)} = \max_{h \in F_S(k,f)} \left\{ \frac{\sum_{g \in F_H(k,h) \cup F_S(k,h)} b_{max}(k,g) - l_{min}(h) + l_{LP,max}(k,h)}{R(k) - \sum_{g \in F_H(k,h)} r_{max}(k,g)} + \frac{l_{min}(h)}{R(k)} \right\}$$

- **End-2-End delay bound for stream f:** $d_{max}(f) = \sum_{k=1}^{n} d_{BU,max}(k,f) + \sum_{k=1}^{n} d_{MD,max}(k) + \sum_{k=2}^{n} d_{AT,max}(k) + \sum_{k=2}^{n} d_{PR,max}(k)$

Dynamic Stream Admission for ATS

- **Assumptions**
  - Information is limited to devices and streams along the path from talkers to listeners
  - Only the per-class parameters are configured via management
    - e.g. max. reservable bandwidth and max. per-hop delay bound of each ATS SRclass
  - Streams are established under the control of a stream reservation protocol
- **Per-hop delay bound**
  - a **per-class per-port** parameter, added to accumulated latency for all the streams associated with the same SRclass
  - not the maximum calculated over the currently reserved streams
  - but **the upper bound value** that limits the number of streams that can be reserved within the allocated bandwidth
- **Stream admission control**

  executed by the reservation protocol for each stream reservation request to check whether adding this stream meets the following constraints on each bridge along the path

  - **Bandwidth constraints:** not exceeding the maximum reservable bandwidth
  - **Latency constraints:** not exceeding the per-hop delay bound
  - **Resource constraints:** not exceeding the available resources, e.g. queuing buffers, FDB, shaper FSMs, etc.

  A stream can be admitted only when it meets all these constraints on all bridges along the path.

Example Dynamic Admission Scheme for ATS

- **Per-class per-port** parameters set by management

Assume one or more SRclasses associated with ATS, each denoted as $\boldsymbol{ClassX}$

AdminMaxPerHopDelay	Max. per-hop delay	$D_{max}(k, ClassX)$
MaxAvailableBandwidth *	Max. reservable bandwidth (in % of port tran. rate)	$R_{max}(k, ClassX)$
MaxInterferingSize	Max. size of an interfering frame	$L_{LP,max}(k)$

* e.g., by use of the ***deltaBandwidth*** and ***lockClassBandwidth*** managed objects specified in Clause 34 FQTSS

- **Per-stream** parameters used for admission control and resource allocation on the bridge at k^th hop

CommittedBurstSize	Max. burst size	$b_{max}(k, f)$
CommittedInformationRate	Max. information rate	$r_{max}(k, f)$
MaxFrameSize	Max. frame length	$l_{max}(k, f)$
MinFrameSize	Min. frame length	$l_{min}(k, f)$

Note*: In the process of stream reservation, these per-stream parameters need to be recalculated on each hop along the stream path, by taking into account the bridge's media-dependent overheads and local clock deviations. (See TSpec discussion later)*

Example Dynamic Admission Scheme for ATS *(Cont.)*

- **Local routines for admission control** of a stream f transmitted with the SRclassX on the k[th] hop
  - Determine the stream paramters $[\boldsymbol{b_{max}(k,f)}, \boldsymbol{r_{max}(k,f)}, \boldsymbol{l_{max}(k,f)}, \boldsymbol{l_{min}(k,f)}]$
  - Check **bandwidth constraints** with $\boldsymbol{r_{max}(k,f)} \leq \boldsymbol{currentAvailableBandwidth(k, ClassX)}$
  - Check **latency constaints** with $\boldsymbol{d_{max}(k,f)} \leq \boldsymbol{D_{max}(k, ClassX)}$
    - while $\boldsymbol{d_{max}(k,f)}$ is the maximum per-hop delay calculated for stream f and all currently reserved streams by using the ATS latency math for the per-hop delay bound described in Annex X of P802.1Qcr/D1.0

$$\underbrace{d_{max}(k,f)}_{\text{The max. among current streams incl. stream } f} = \underbrace{d_{AT,max}(k) + d_{PR,max}(k) + d_{MD,max}(k)}_{\text{stream-independent terms}} + \underbrace{d_{BU,max}(k,f)}_{\text{stream-dependent terms using info of stream } f \text{ and all currently reserved streams}}$$

  - Check **resource constaints**
    - $\boldsymbol{b_{max}(k,f)}$ and $\boldsymbol{l_{max}(k,f)}$ could be used as input for calculation of the buffer sizes required by stream f
    - However, the algorithm used for caclulation of availalbe resources for a stream e.g. the queuing buffer, strongly depends on bridge implementation.

Traffic Specification for ATS (1)

- **Recap: SRP TSpec for AV streams using CBS**
  - using the triple ***{MaxFrameSize, MaxFramesPerInterval, classMeasurementInterval}***
  - defined by a Talker, specifying the traffic shape output from the Talker
  - propagated unchanged by bridges to Listener(s)

- **Requirements on TSpec for streams using ATS**
  - not restricted to use of the interval-based pattern
  - support for a more general traffic pattern described by talkers using token bucket parameters (b,r)
  - taking account of changes in traffic characteristics at each hop, e.g. caused by clock deviations

- **Suggested TSpec parameters for ATS (cmp. P802.1Qcr/D1.0 Annex X)**
  - *CommittedInformationRate*: Reflects the *CommittedInformationRate* parameter, but accounts for *local* async. Clock rate inaccuracies during propagation
  - *CommittedBurstSize*: Reflects the *CommittedBurstSize* parameter
  - *MinFrameSize, MaxFrameSize*: Frame size bounds

Traffic Specification for ATS (2)

- **Propagation of *CommittedInformationRate*** from Talker to Listener
  - At the k^th hop, *CommittedInformationRate* is a function of the same parameter at the prev. hop and the ClockRateDeviationMax parameters of both adjacent devices:

$$CommittedInformationRate\ (k,f) = \underbrace{\frac{1}{1-10^{-6}ClockRateDeviationMax(k)}}_{\text{Known to the k}^{\text{th}}\text{ device}} \times \underbrace{CommittedInformationRate\ (k-1,f)\left(1+10^{-6}ClockRateDeviationMax(k-1)\right)}_{\text{Sent from the (k-1)}^{\text{th}}\text{ device to the k}^{\text{th}}\text{ device}}$$

- **Interoperability with AVB end-stations**

  An example of converting MSRPv0 TSpecs of AV streams to ATS TSpecs for transmission with ATS in the network.

$$CommittedBurstSize(1,f) = MaxFramesPerInterval(f) \times \left(MaxFrameSize(f) + portMediaDependentOverhead(1)\right) \times 8$$

$$CommittedInformationRate(1,f) = \frac{MaxFramesPerInterval(f) \times (MaxFrameSize(f) + portMediaDepenentOverhead(1)) \times 8}{Interval(f)}$$

- **Changing frame lengths (work in progress)**
  - *portMediaDependentOverhead* may vary along the path
  - Tags may be added or removed, e.g. redundancy Tag of 802.1CB
  - Solution space: from standardized bounds, bounds distributed by Talkers, …, exact delay impact computation, with additional traffic characterization

Summary

- Contribution to P802.1Qdd for support of TSN transmission mechanisms
- ATS support in RAP outlined on previous slides
- Work-in-progess: TSpec
- Interoperability of ATS network with AVB end-stations