AFDX networks

By: J. Javier Gutiérrez (gutierjj@unican.es)

Computers and Real-Time Group, University of Cantabria

ArtistDesign Workshop on Real-Time System Models for Schedulability Analysis

Santander, 7-8 February 2011

Introduction to AFDX networks

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AFDX (Avionics Full Duplex Switched Ethernet) is a communications network defined in the ARINC-664, Part 7 standard:

- point to point full duplex Ethernet links (redundant)
- special purpose switches with preconfigured routing
- two main types of communication ports:
  - *Sampling Port*: the arriving message overwrites the current message stored in the buffer
  - *Queueing Port*: the arriving message is appended to a FIFO queue
- UDP/IP protocol is used for transmission
- traffic regulation is made in transmission via *Virtual Links*

Traffic regulation in AFDX

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Each virtual link (VL) is characterized by two parameters:

- the largest Ethernet frame (Lmax): a value in bytes that can be transmitted on the VL
- the Bandwidth Allocation Gap (BAG):
  - the minimum interval in milliseconds between Ethernet frames transmitted on the VL
  - a power of 2 value in the range [1,128]

Each virtual link has a FIFO queue for all the fragmented packets:

- the same VL can be shared by several ports, tasks or partitions
  - It can cause a poor schedulability of the system
- there is no way to prioritize messages on a VL

Maximum jitter

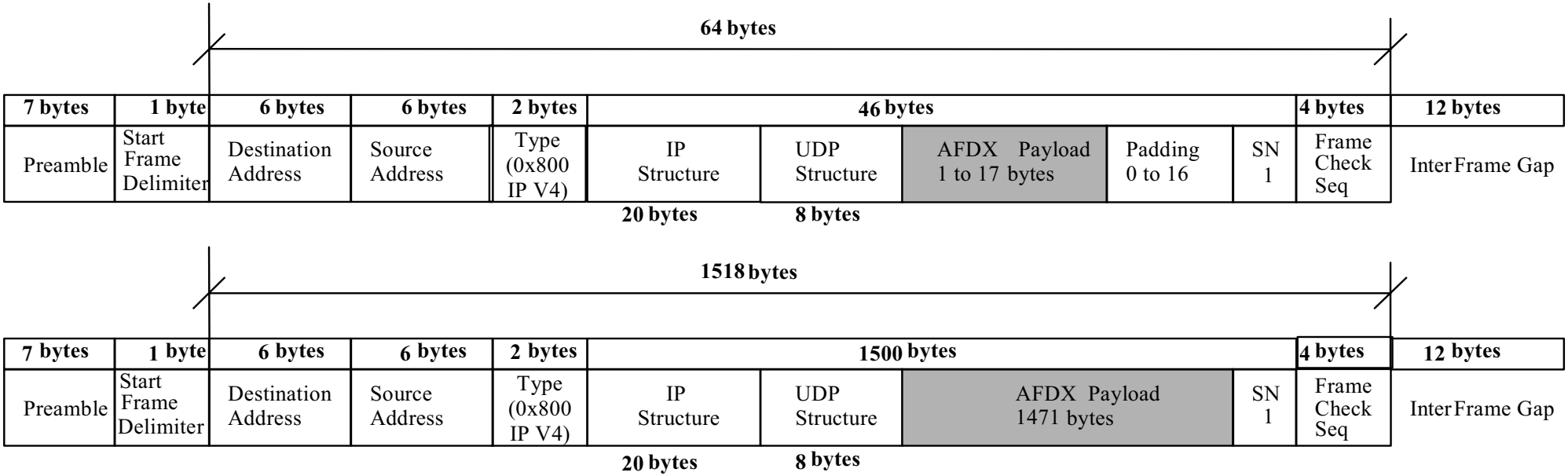
The maximum allowed jitter on each VL at the output of the end system should comply with both of the following formulas:

$$MaxJitter \leq 40\mu s + \frac{\sum_{i \in \{set\,of\,VLs\}} ((20 + Lmax_i) \cdot 8)}{N_{bw}}$$

$$MaxJitter \leq 500\mu s$$

- N_{bw} is the speed of the Ethernet link in bits per second
- 40 μs is the typical minimum fixed technological jitter

Ethernet frame



- **Lmax should be in the interval [64,1518]**

Sub-Virtual Links

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A virtual link can be composed of a number of Sub-Virtual Links

Each Sub-VL has:

- **a dedicated FIFO queue**
- **a round robin algorithm working over IP fragmented packets**

Latency in the transmission

If fragmentation is not required and the messages are produced at a frequency that is equal to or lower than the *BAG* of the VL:

$$MaxLatency \leq BAG + MaxJitter + L_T$$

- **L_T is the technological latency in the transmission (it should be lower than 150μs).**

If fragmentation is required or messages are produced in bursts, the latency for packet *p* (with *p*-1 packets waiting in the VL FIFO queue):

$$MaxLatency(p) \leq p \cdot BAG + MaxJitter + L_T$$

AFDX switch

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Transmissions to or from the switch are made using the full capacity of the physical link

Packets are delivered in a store and forward way:

- the hardware latency of the switch should be taken into account

A new source of jitter appears in the FIFO queue where packets should wait to be sent to the destination end system

Latency in the reception

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Once a message is completely received, it is enqueued at the corresponding AFDX port

- it could potentially overflow

The technological latency of the end system in reception, L_R, should be lower than 150μs

Modelling

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The model is similar to the one for the analysis of tasks

We consider two types of messages:

- ***Synchronized:***
  - **the release times of these messages are relative to a general and *common reference of time***
  - **an *offset* to represent the interval between the start of the MAF (Major Frame) and the earliest release of the message**
- ***Non-synchronized*: messages can be released at any time**

Modelling (cont'd)

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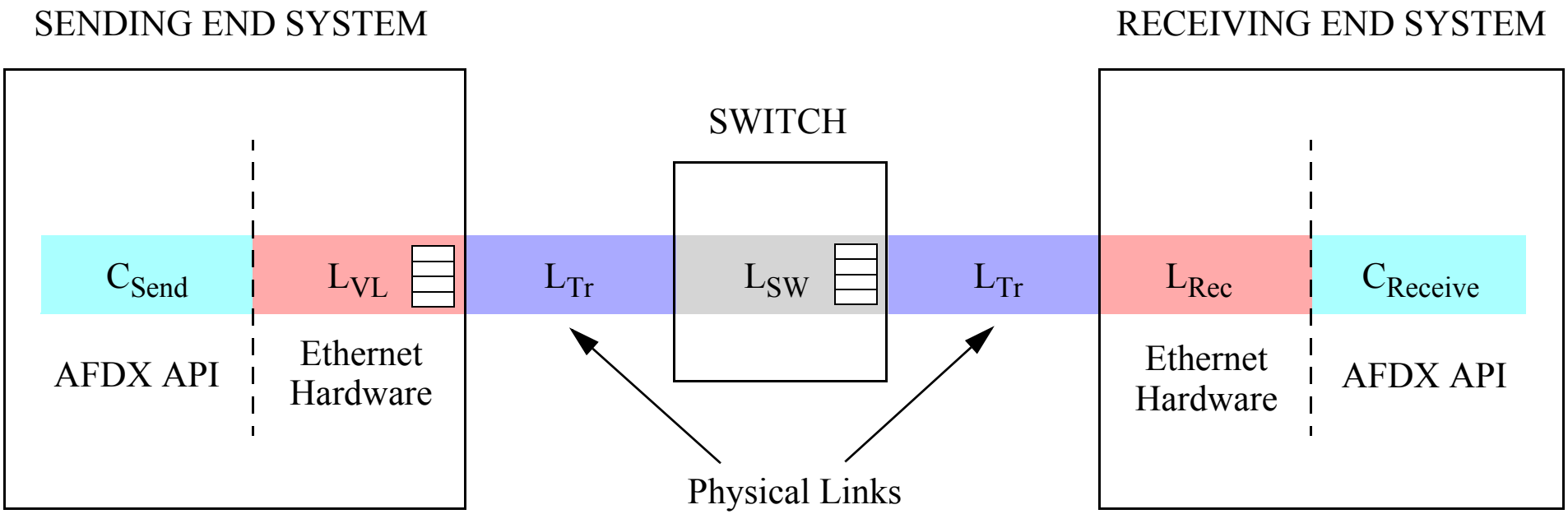
Different types of parameters to model AFDX communication:

- **message stream parameters**
  - M_i, p_i, Np_i, N_i, M_i^b, p_i^b, Np_i^b, N_i^b, T_i, Φ_i, J_i, Source(σ_i), L_i, L_i^b
- **VL parameters**
  - BAG_j, $Lmax_j$, SourcePorts(VL_j), DestinationPorts(VL_j)
- **hardware parameters**
  - N_{bw}, L_T, L_{Tmin}, J_{Tech}, L_R, L_R^b, L_S^b
- **Ethernet frame and protocol parameters**
  - O_{Eth}, O_{Prot}, N_{min}

Latency Model



- 5 steps in the communication process
- 2 contention points: queueing in the sending end system (L_{VL}) and queueing in the switch (L_{SW})

AFDX in MAST-2

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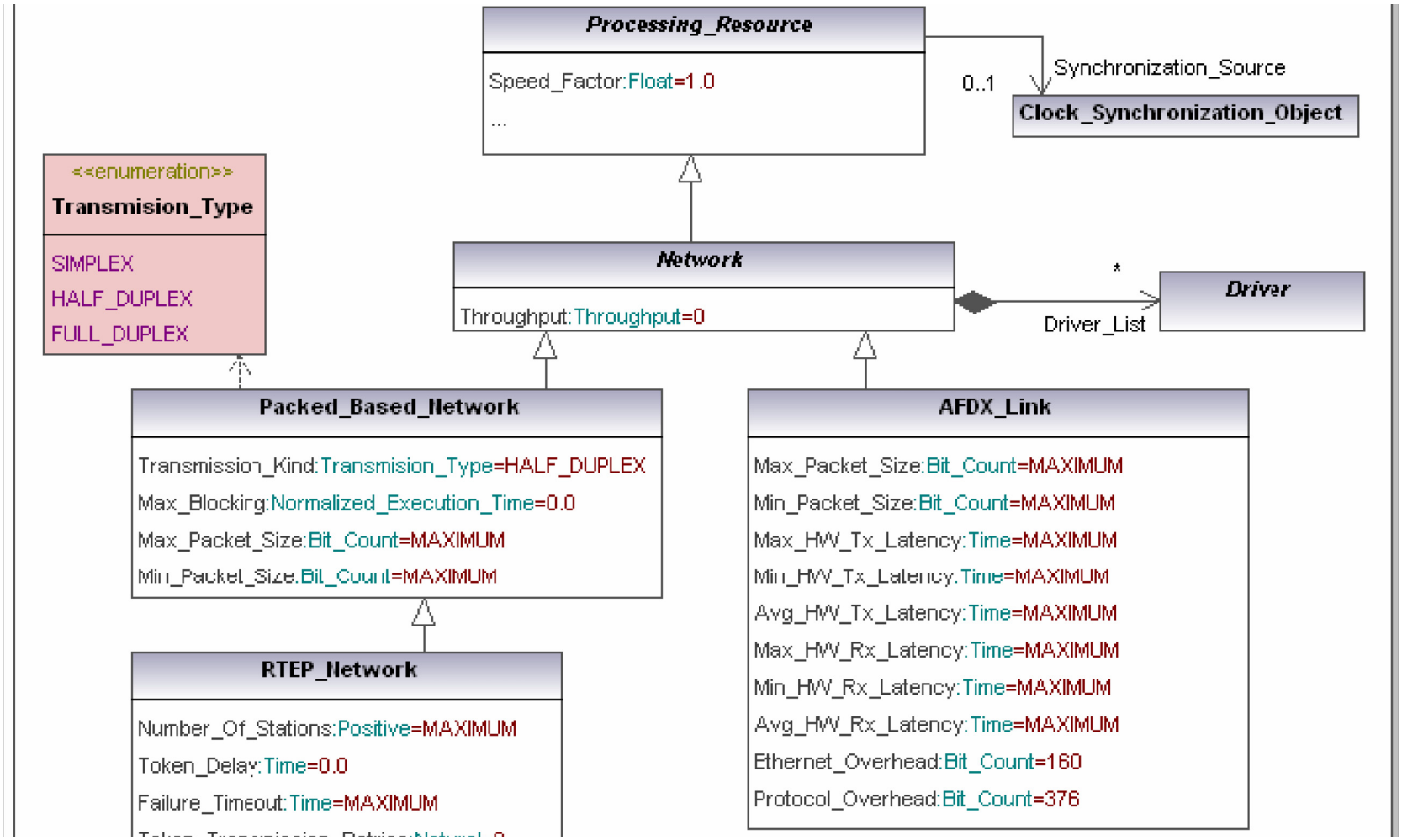
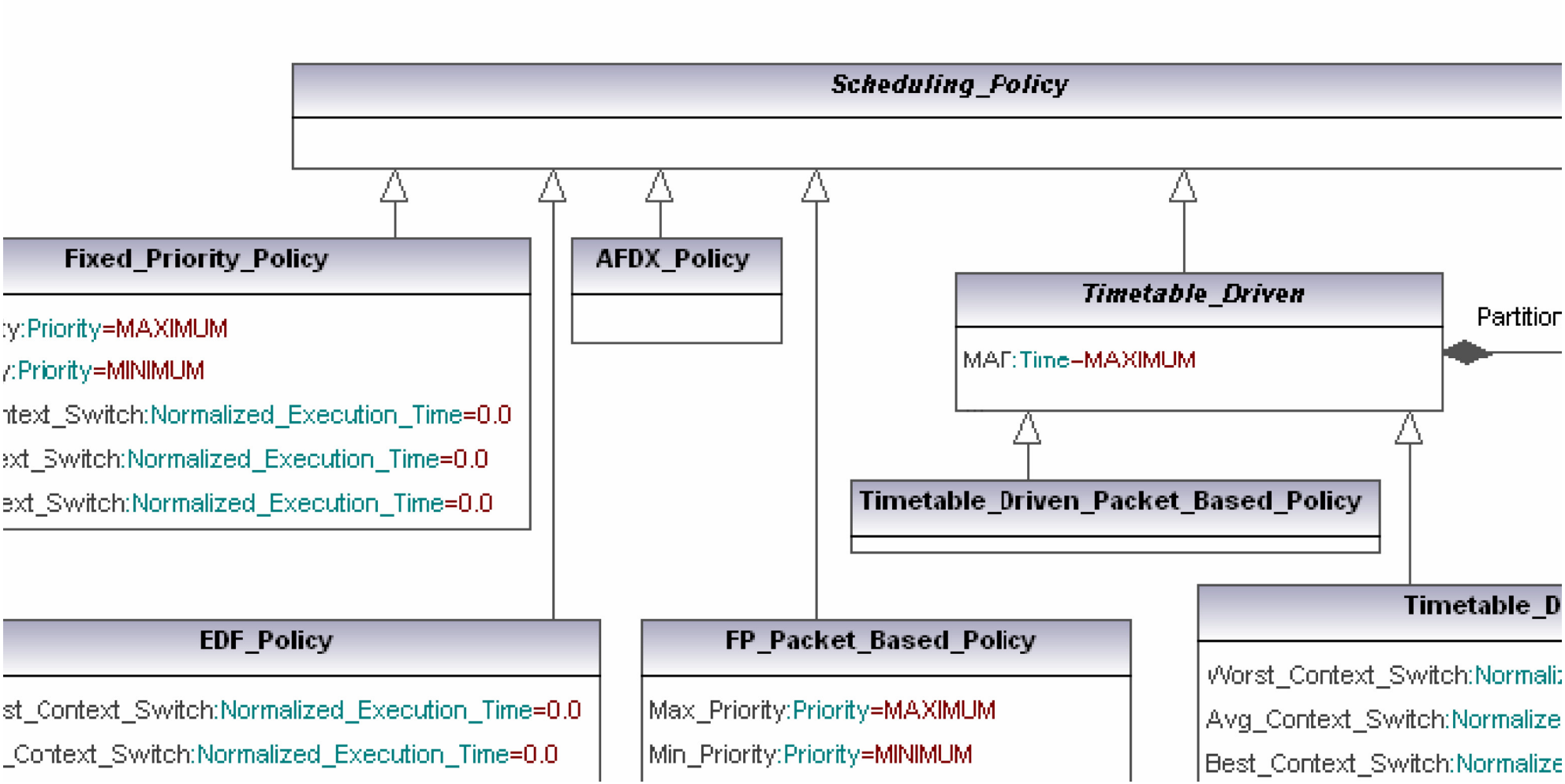
- Processing Resources
  - Network: AFDX_Link
  - Network_Switch: AFDX_Switch
- Scheduling Policy
  - AFDX_Policy
- Scheduling Parameter
  - AFDX_Virtual_Link
- Schedulable Resource
  - Communication_Channel
- Event Handler
  - Message_Event_Handler: Message_Delivery, Message_Fork

AFDX in MAST-2: Network



AFDX in MAST-2: Scheduling Policy



AFDX in MAST-2: Scheduling Policy (cont'd)

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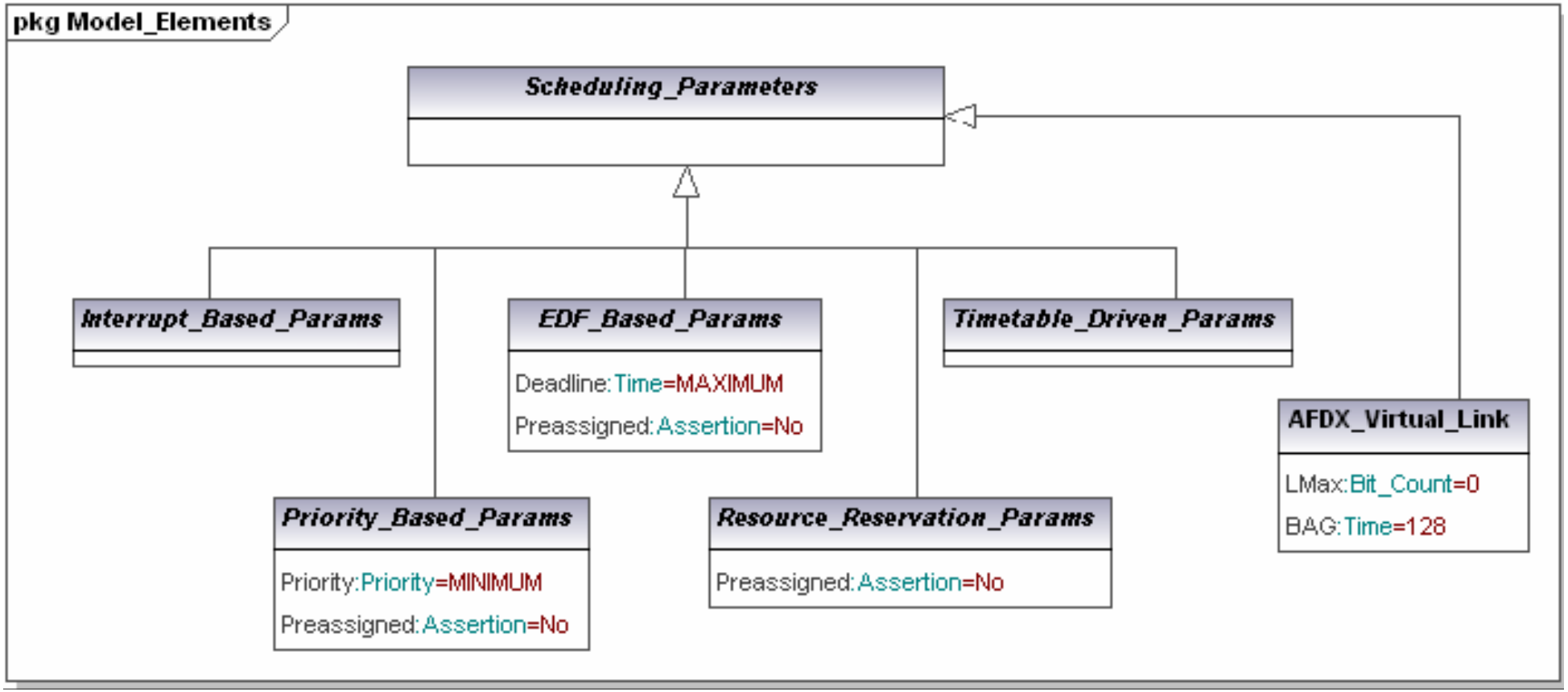
AFDX_Policy:

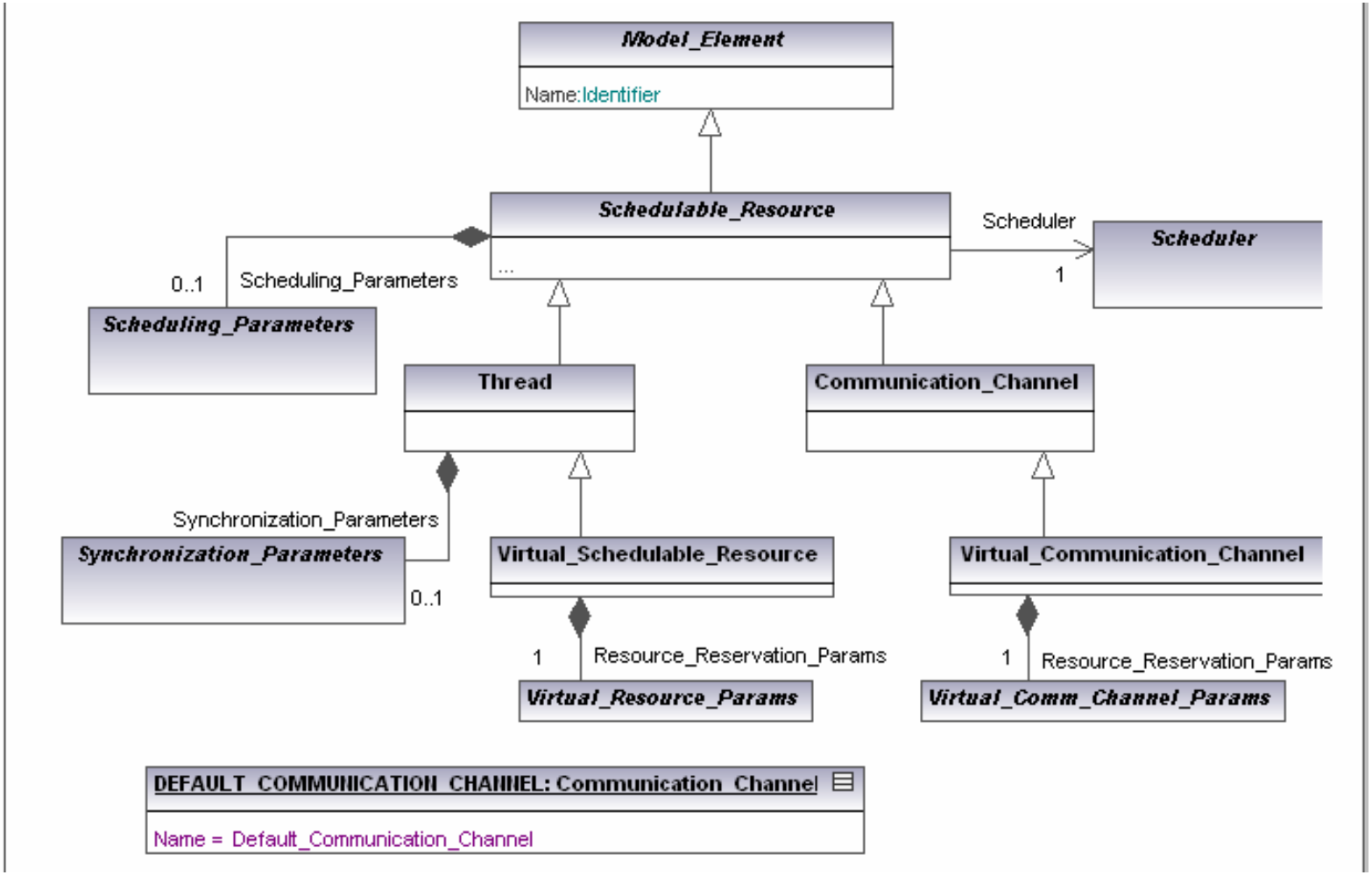
- **messages are scheduled through virtual links**
- **messages are scheduled in FIFO order when they are originated at an AFDX switch**

This policy may only be assigned to a scheduler that has an AFDX_Link as its host

AFDX in MAST-2: Scheduling Parameters



AFDX in MAST-2: Schedulable Resource



AFDX in MAST-2: Schedulable Resource (cont'd)

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DEFAULT_COMMUNICATION_CHANNEL:

- used for communications through AFDX links when the message is originated at an AFDX switch
- the implicit scheduling policy is FIFO ordering for the messages

AFDX in MAST-2: Switch

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It is capable of delivering messages arriving at an input port to one or more output ports

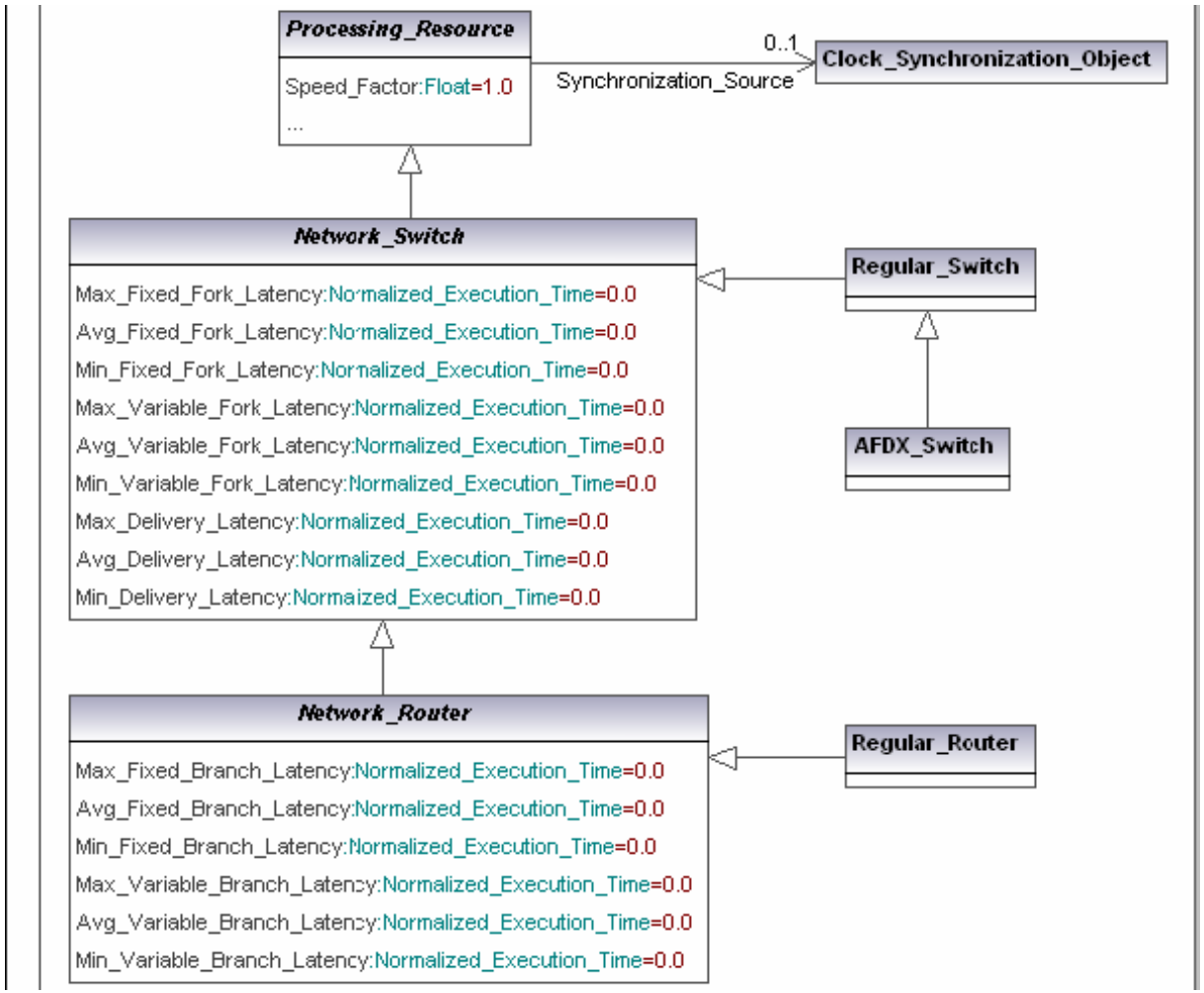
The delivery operations are specified through special-purpose *message event handlers*

MAST does not require to define the network topology (it is implicit in the end-to-end-flow)

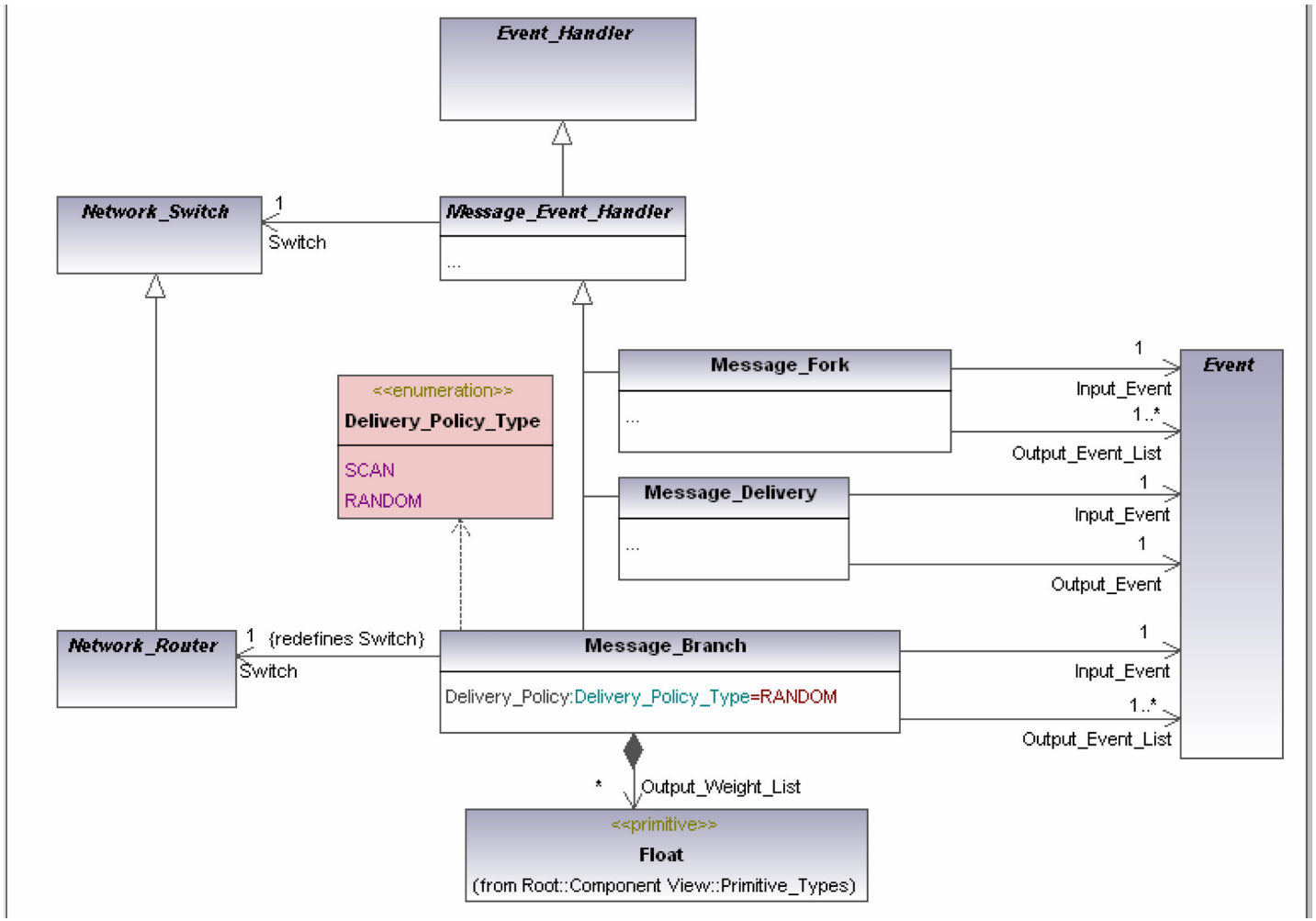
It is assumed a shared memory switch in which messages do not need to be copied

Contention occurs when several messages need to be sent to the same output port, in which case a queue is used at the output port

AFDX in MAST-2: Switch (cont'd)



AFDX in MAST-2: Message_Event_Handler



Example: sending a message through a switch