IEC/IEEE 60802
End station model
Requirements and assigned features

- Transmit direction
- Enhanced transmission selection (ETS)

- Receive direction

- Synchronization model

- Examples

Version V04 – February 2021

Günter Steindl (Siemens AG)

Industrial Automation Verticals

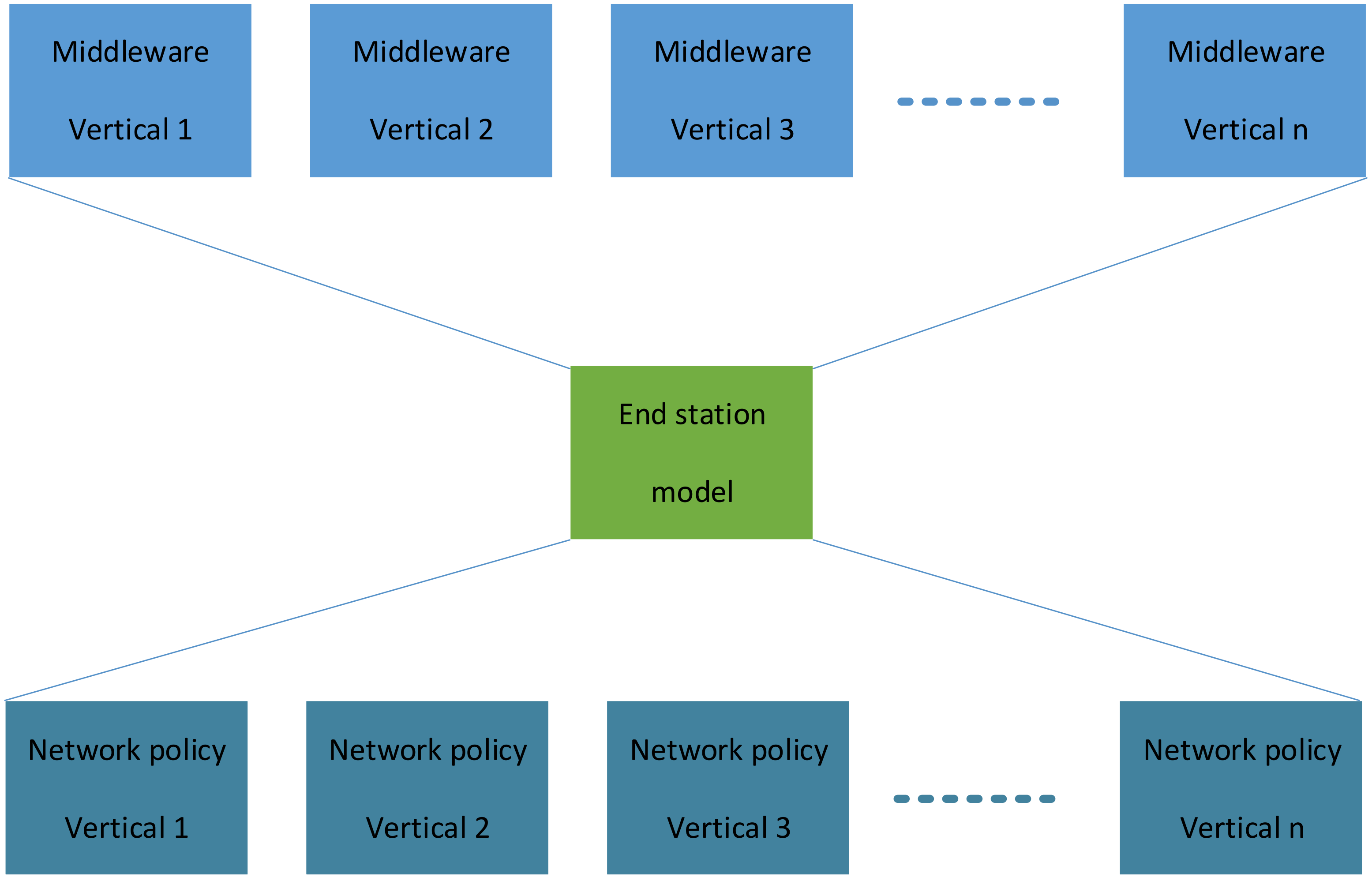
End stations used in industrial communication are often used in more then one vertical.

Thus, the end station model need to cover requirements from these verticals.

Factory automation, Process automation, Motion control, Transportation systems, Building automation and Power generation are just an example for these verticals.

They may rely on different middleware or different network policies but share a similar end station model.

Principle



Middleware Vertical 1
Middleware Vertical 2
Middleware Vertical 3
Middleware Vertical n
End station model
Network policy Vertical 1
Network policy Vertical 2
Network policy Vertical 3
Network policy Vertical n

General Requirements

End stations implementing industrial communication protocols are often able to consume the whole bandwidth available at the Ethernet interface.

Thus, disciplining the network access to limit the bandwidth usage is required to avoid immediate frame dropping at the first bridge.

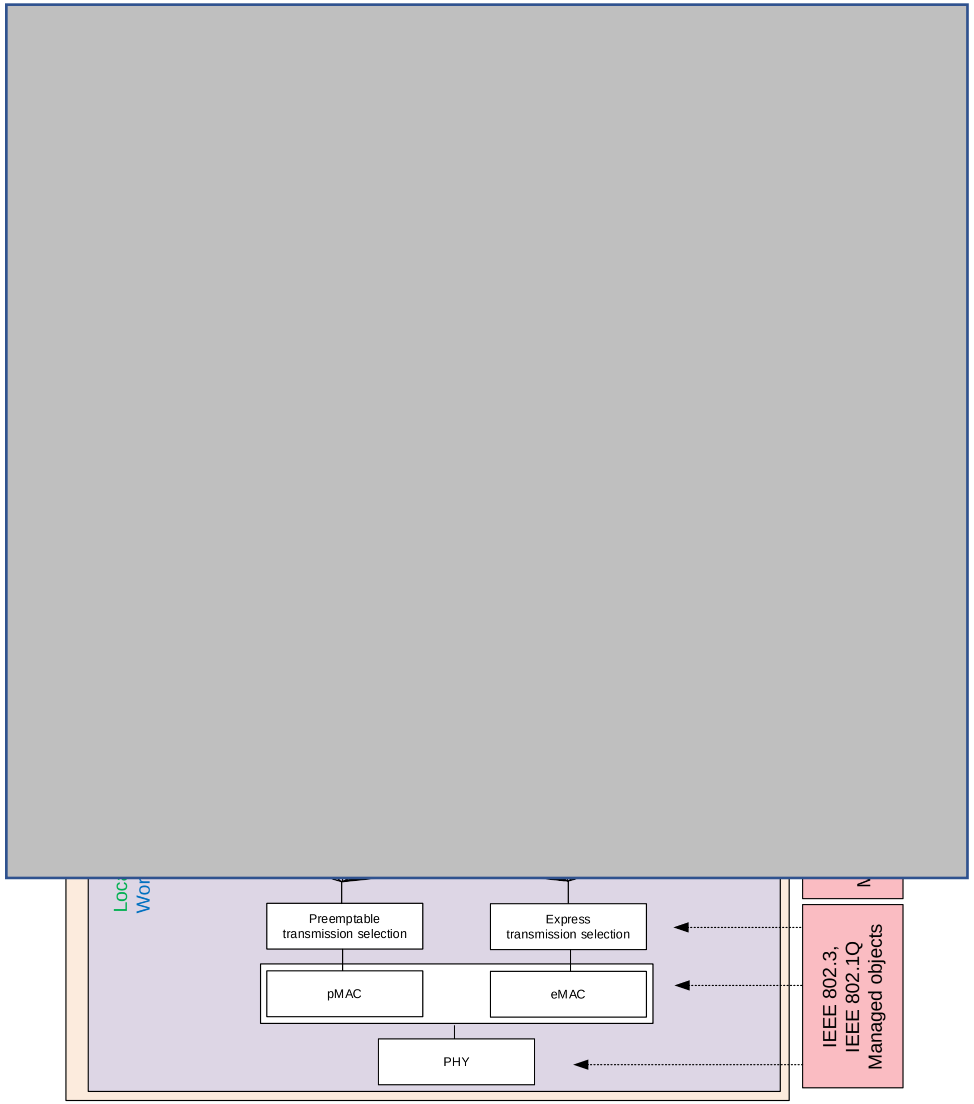
Additionally, knowing about the disciplined interfaces supports the network calculus of a Digital Twin.

Content

1. Transmit direction
2. Receive direction
3. Synchronization model
4. Example
5. Conclusion

Transmit direction

End station model



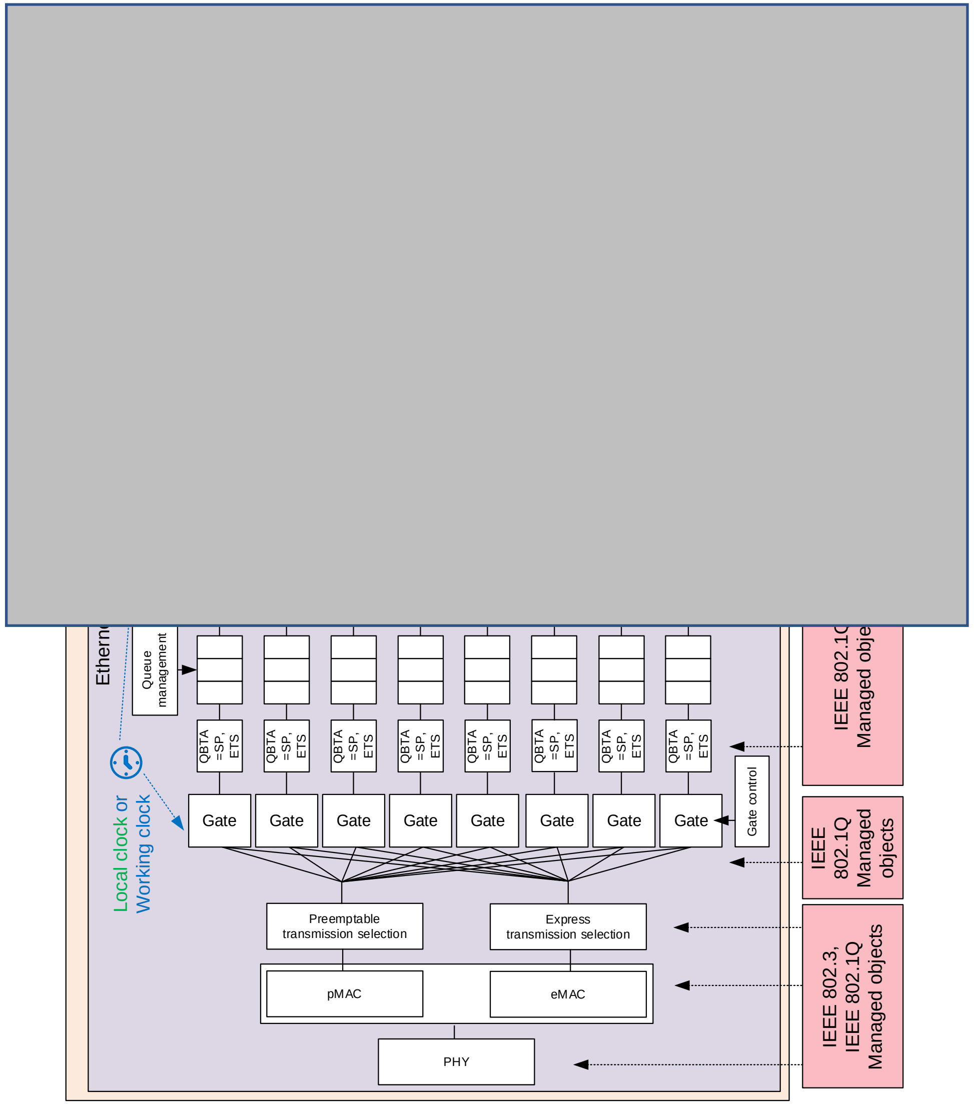
Requirement:

- Data rates from 10 Mbit/s to 10 Gbit/s
- Single Pair Ethernet for Sensors/Actors
- Latency optimized transmit and receive

Solved by:

- IEEE 802.3 MAU types
- Preemption (MAU type dependent)

End station model



Requirement:

- Disciplined network access for all traffic classes
- Latency optimized transmit and receive

Solved by:

- Enhancements for scheduled traffic for end-stations (802.1Q)
- Enhanced transmission selection (802.1Q)
- Working Clock (802.1AS)

Enhanced transmission selection

Requirements

ETS (DXCB optional) is intended to allow the bandwidth control for the queue not used for streams.

Example:

Use a MEF10.3 defined algorithm (one envelope, color blind, bandwidth sharing, [per queue] buckets)

Enhancements for scheduled traffic are used to define one window for the queues controlled by ETS

For each of this queues an amount of bandwidth per time is assigned

If the amount of bandwidth is consumed, the next queue/priority is transmitted.

Any leftover of a higher prior queue can be consumed by the lower priority queues.

Even if the window is e.g. 50% of TAS AdminCycle, only the ETS configured amount of bandwidth per time is used by the non-stream queues.

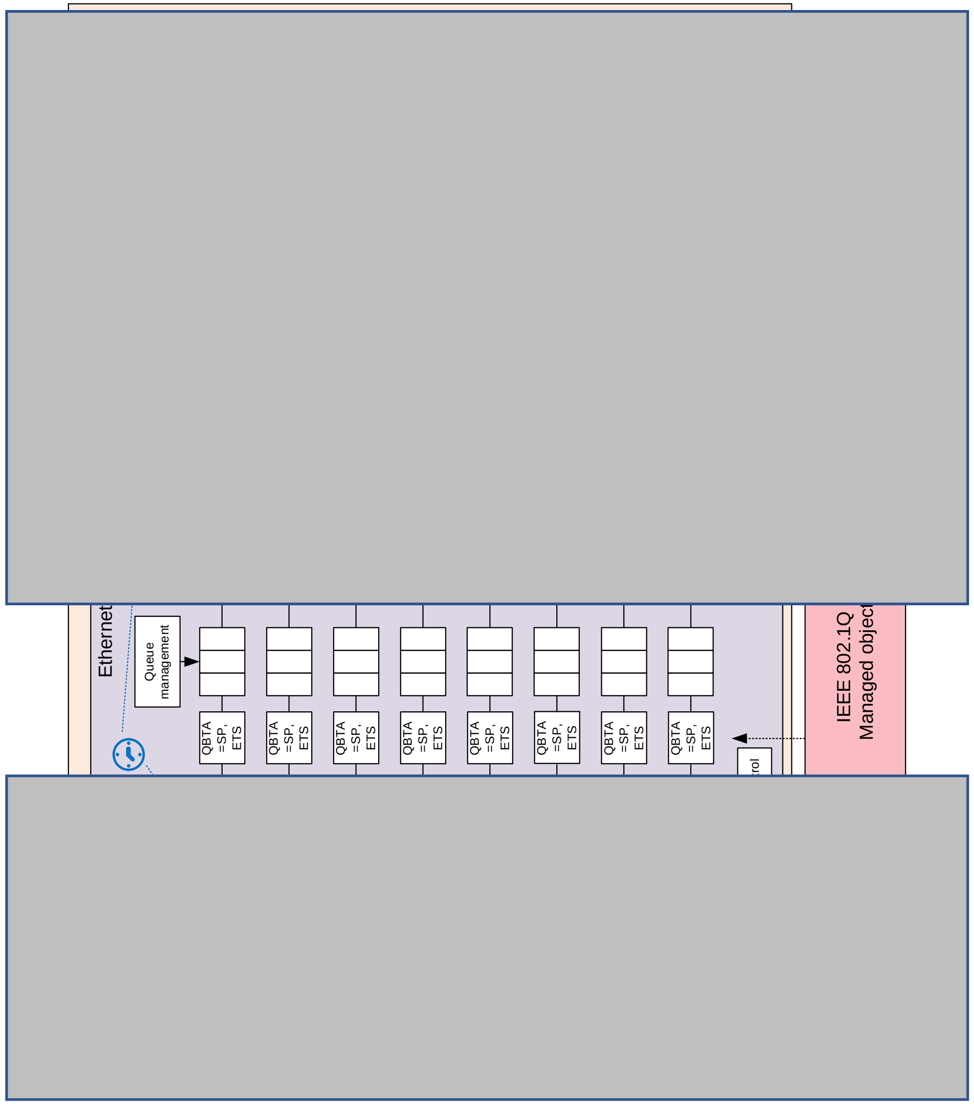
Thus, the amount of bandwidth per time in maximum consumed by an end-station is known upfront and may be limited if needed to stay inside the available bridge resources.

Why not just use a smaller window, e.g. 25%, for non-stream traffic?

- This doesn't solve the requirement for bandwidth limiting per non-stream queue
- Would lead to additional delay (traffic moved to the next occurrence of the window) for non-stream traffic, even if still free bandwidth a non-stream queue is available

Enhanced transmission selection

a Queue Based Transmission Selection Algorithm (QBTA)



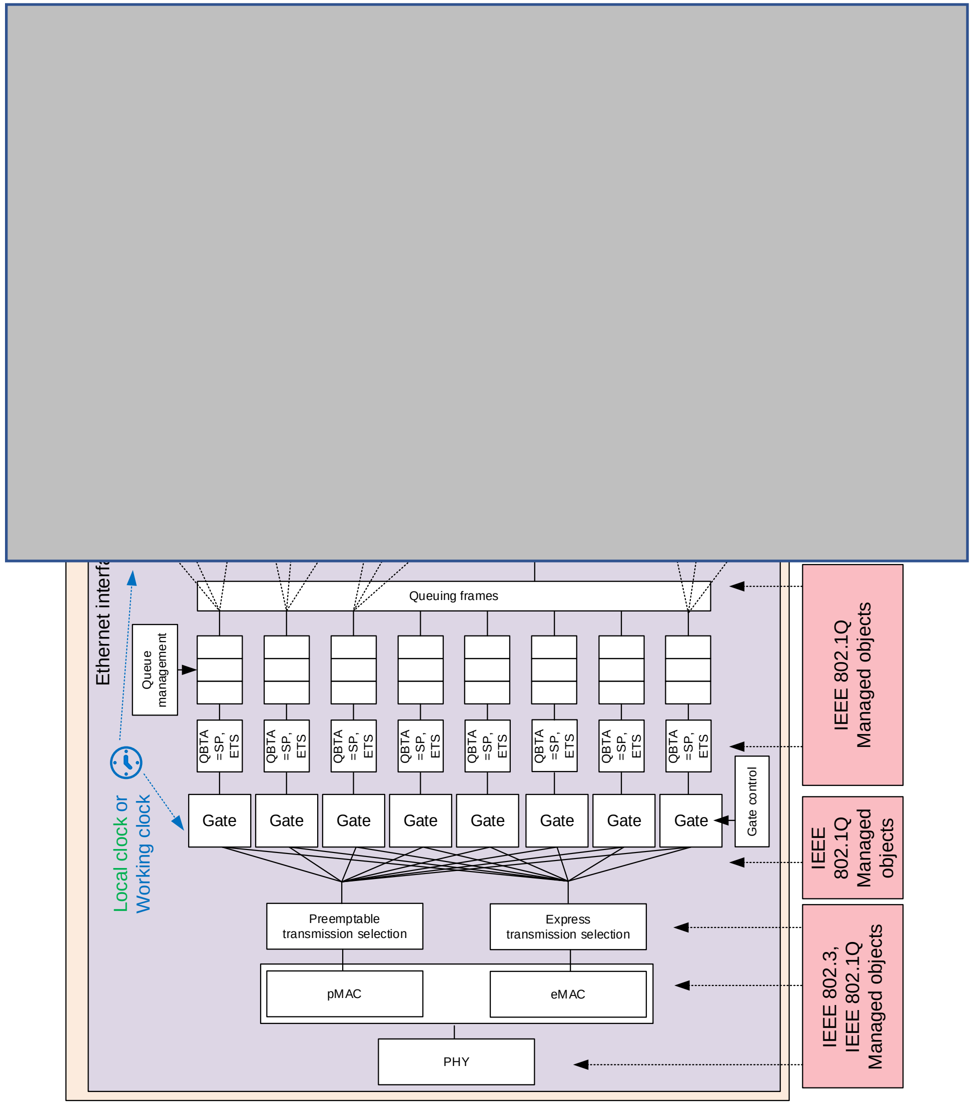
Goal:

- ETS acts as bandwidth limiter for the selected queue.
- Algorithm is configured using xy% (converted into octets / time interval)
- Not coupling with window size / gates / gate control
- Unused bandwidth of a higher priority queue can be consumed by a lower priority queue
- Bandwidth not used in the defined time interval is “lost”

Constraints:

- Time interval needs to be in the range of Admin Cycle, if used together with gate control
- Examples for Admin Cycle time intervals:
  - 25µs/31,25µs to 1ms

End station model



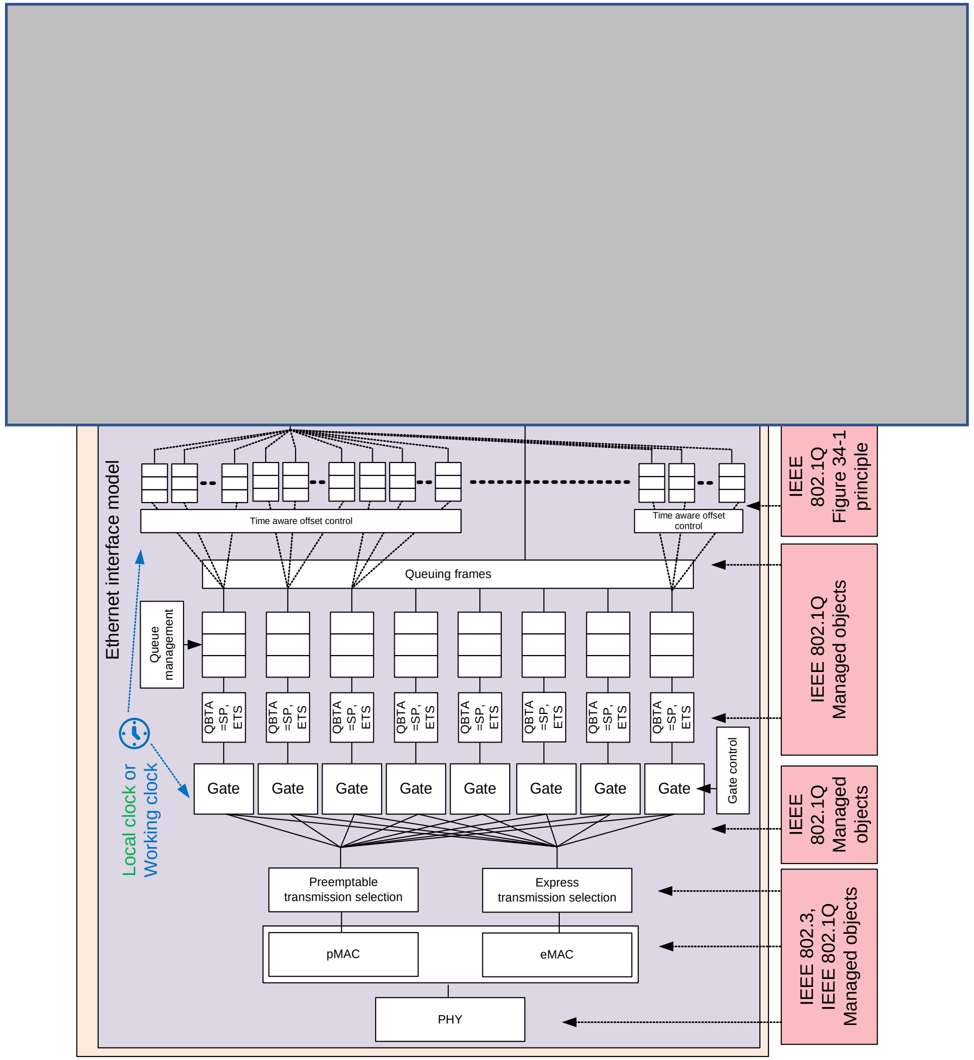
Requirement:

- Up to 8 traffic classes
- Up to 8 cyclic transmitted stream classes
- Up to 8 acyclic transmitted traffic classes

Solved by:

- Traffic class model

End station model



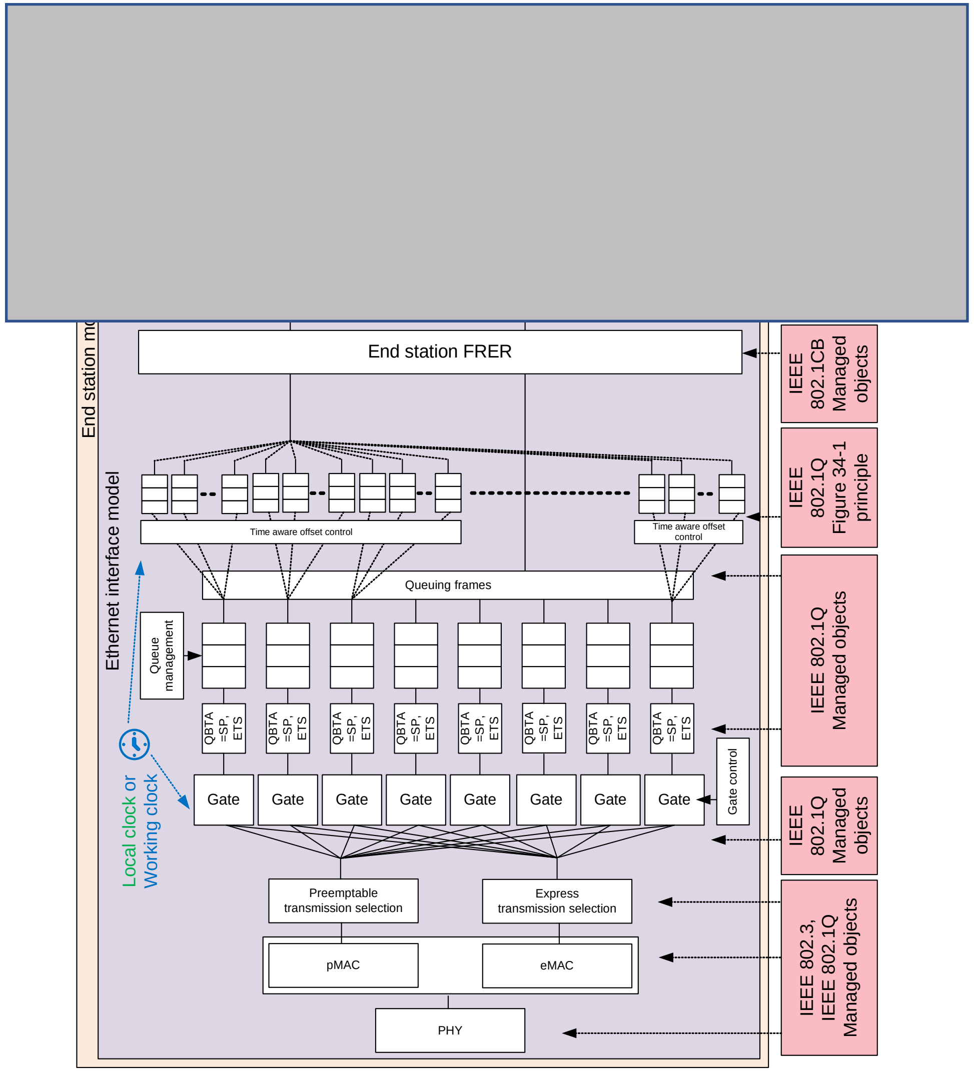
Requirement:

- Support for at least 512 talkers / streams
- Transmit interval 25µs/31,25µs to 1s for cyclic transmitted streams (802.1Q – Obv for end stations)
- Time triggered transmit (802.1Qcc: “time-aware-offset” control)

Solved by:

- Additional stream queues used as input for the traffic classes (following 802.1Q Figure 34-1)
- Working Clock (802.1AS)

End station model



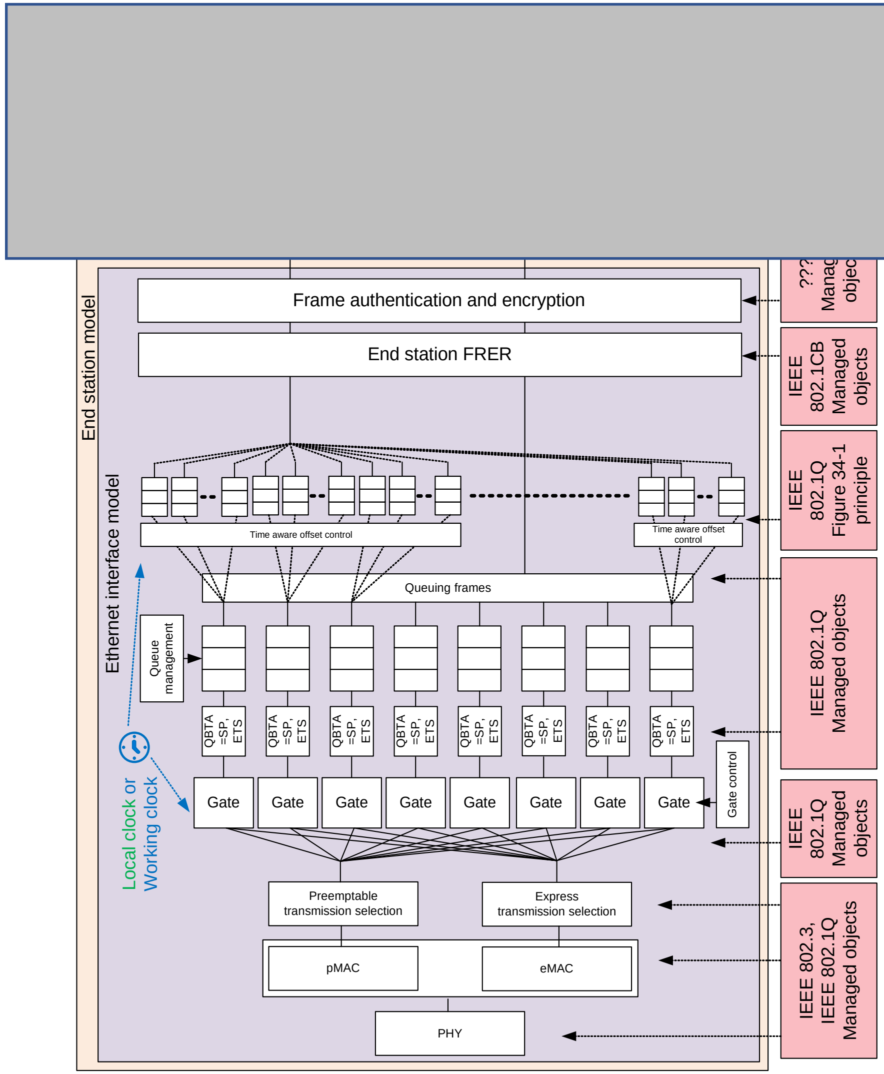
Requirement:

- Seamless / Bumpless redundancy

Solved by:

- IEEE 802.1CB Clause 5.6, 5.7, and 5.8 (partial)
- End station FRER
- If coupled ring are used, additionally network FRER

End station model



Requirement:

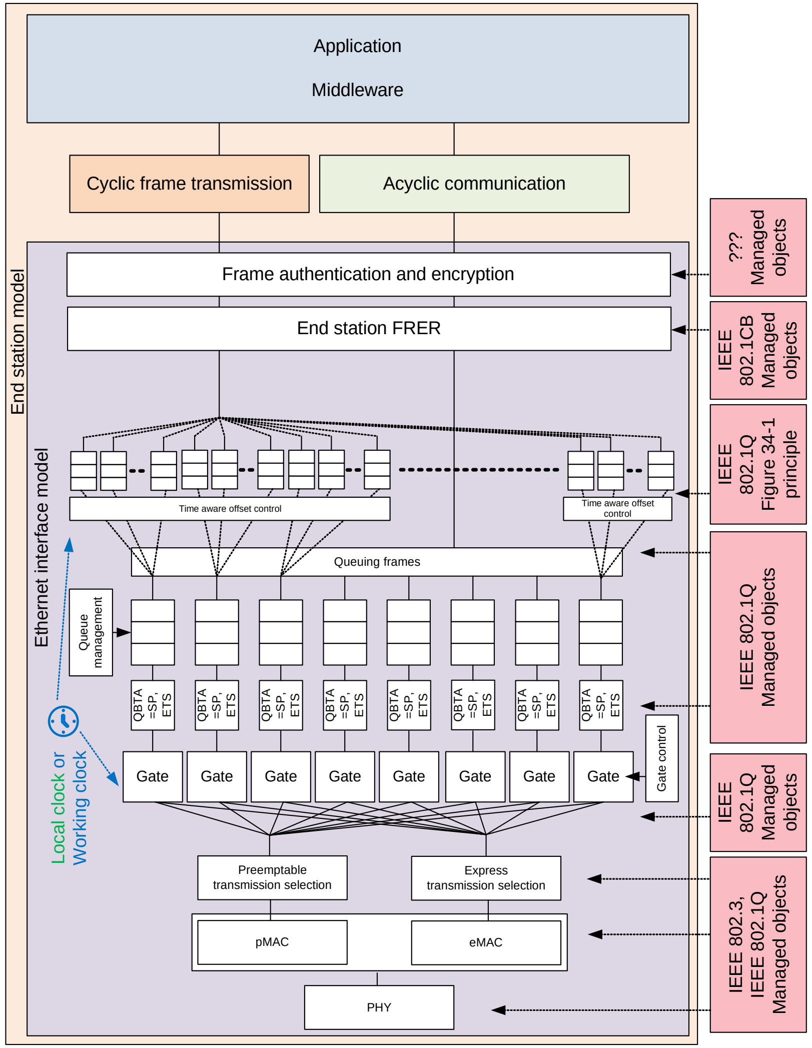
- Security, including device identity, authentication and encrypted authentication

Solved by:

- IEEE 802.1AR, IEEE 802.1X, …
- Device internal trust anchor

Use of IEEE 802.1AE optional

End station model



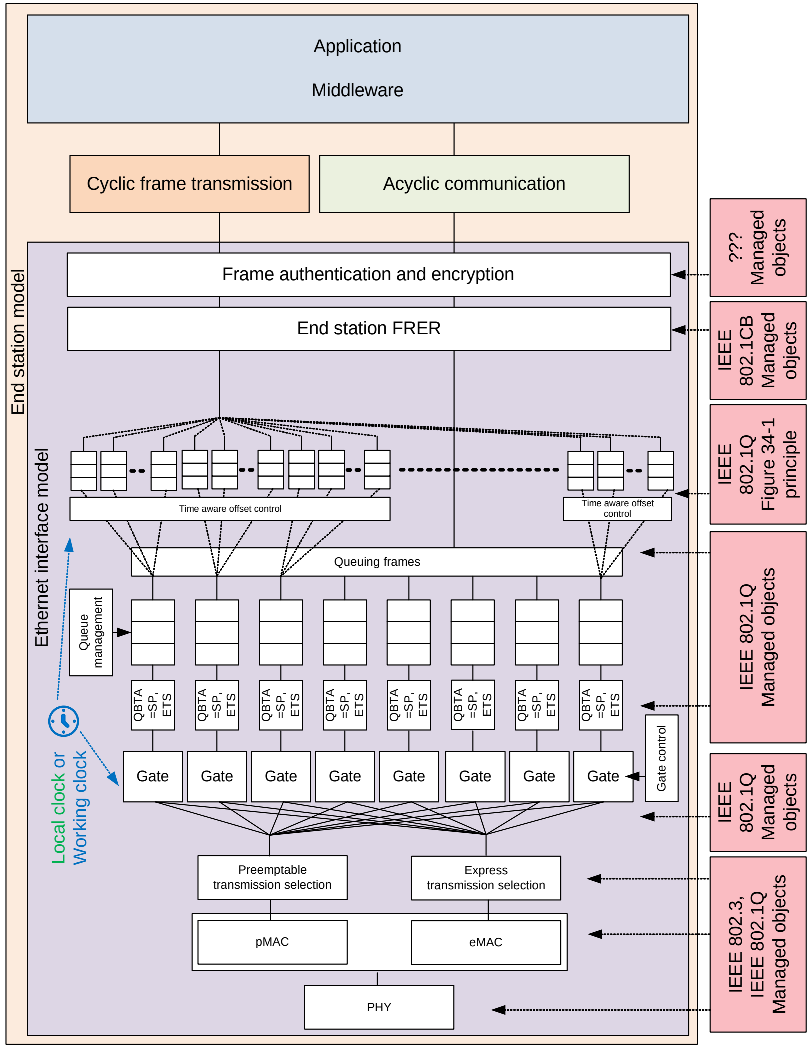
Requirement:

- Middleware requirements from the different industrial automation verticals

Solved by:

- Common end station model

Conclusion

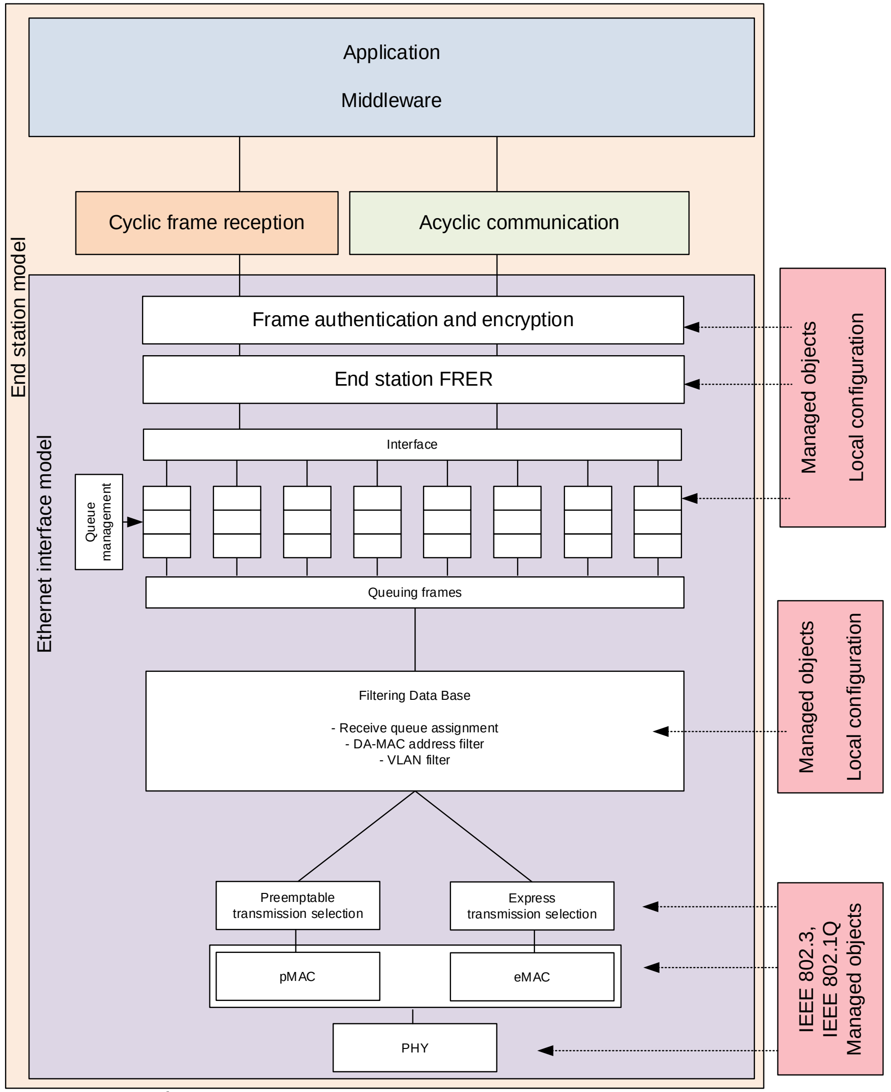


An end station model covering the requirements known by the author of this contribution based on the IEEE802 building blocks can be referenced by the 60802.

The number of traffic classes for cyclic and acyclic communication is derived from the above statement.

Receive direction

End station model – Receive direction

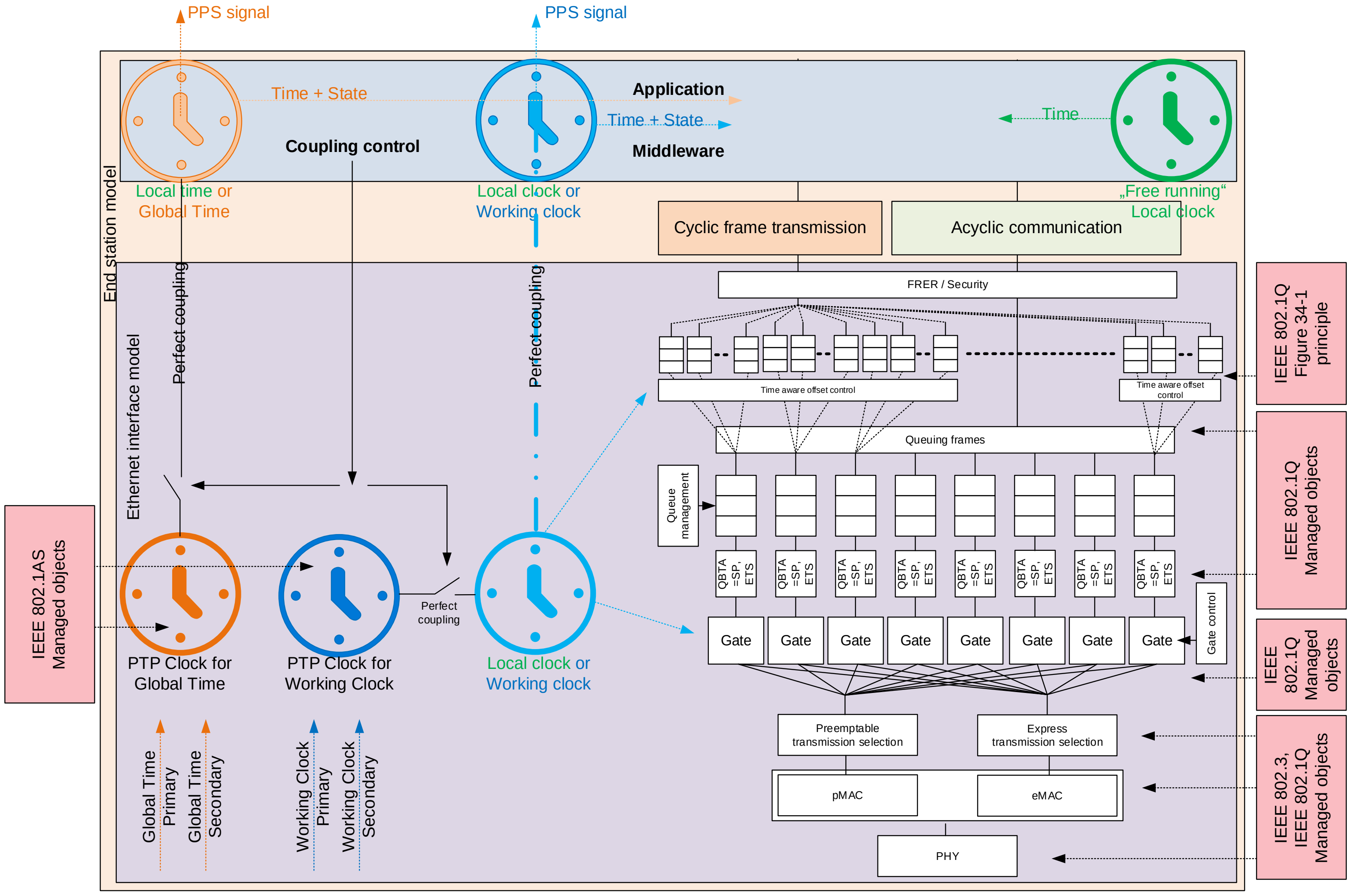


Receive direction

- Preemption
- Receive
  - queue assignment
  - VLAN / VID checking
  - MAC address filtering
- Queue based guaranteed receive resources to ensure zero-congestion loss at the Listener

Synchronization model

Synchronization model



The end station interface and end station model needs to include synchronization.

Working Clock is used by both, end station interface and end station.

Global Time is used by the end station.

Application requires availability of Global Time and Working Clock at all times and thus, the end station maintains two instances of Working Clock and Global Time.

The coupling of these two instances is controlled by the application.

Working Clock timescale is assumed as ARB.

Global Time timescale is assumed as PTP.

Additionally, (just for information) the application uses a free running local clock which make sure that even smallest timespans are only influenced by the oscillator quality.

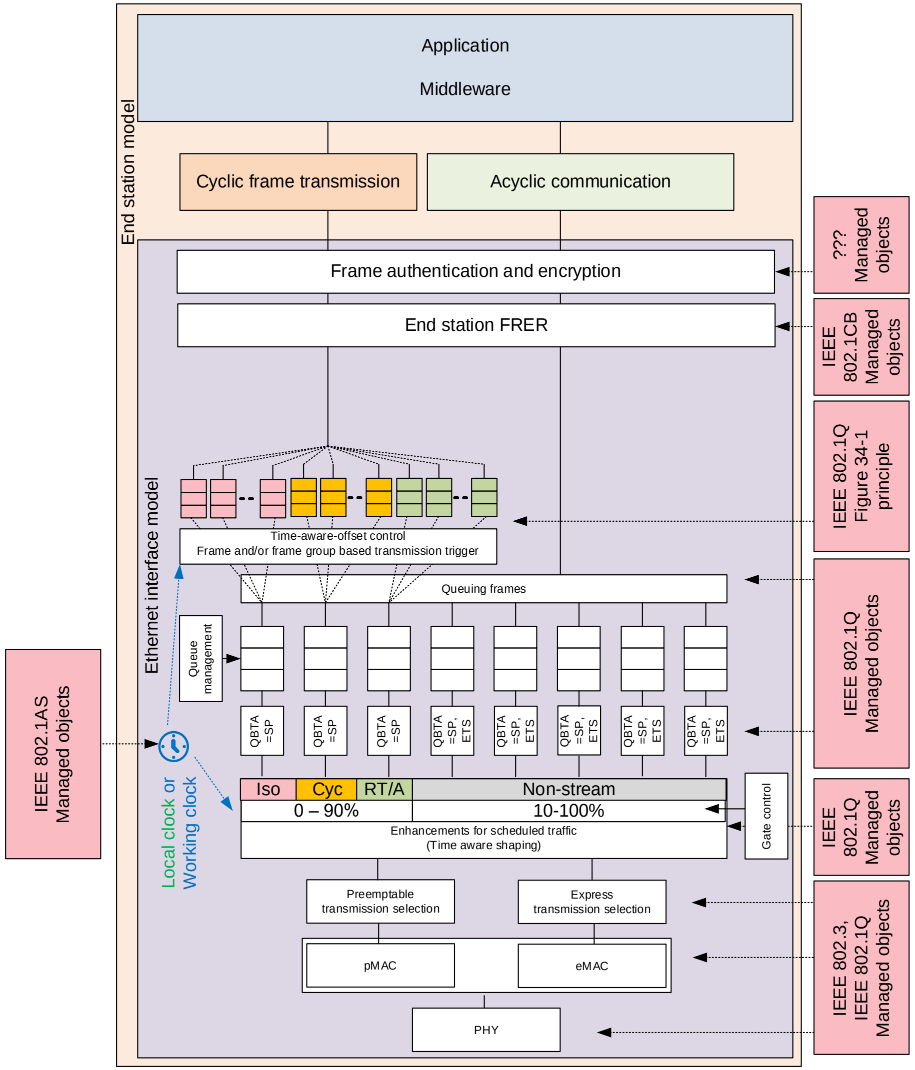
Example

Example usage

Vertical “A” defines the usage of the following traffic classes:

1. Periodic, traffic engineered path, time-sensitive stream, zero congestion loss, defined receive deadline (engineered max latency)
2. Periodic, traffic engineered path, time-sensitive stream, zero congestion loss, engineered max latency
3. Periodic, learned path, time-sensitive stream, defined bandwidth, engineered max latency
4. Event-driven, learned path, defined bandwidth, network management
5. Event-driven, learned path, defined bandwidth
6. Event-driven, learned path, defined bandwidth
7. Event-driven, learned path, defined bandwidth
8. Event-driven, learned path, defined bandwidth

Example applied to end station model

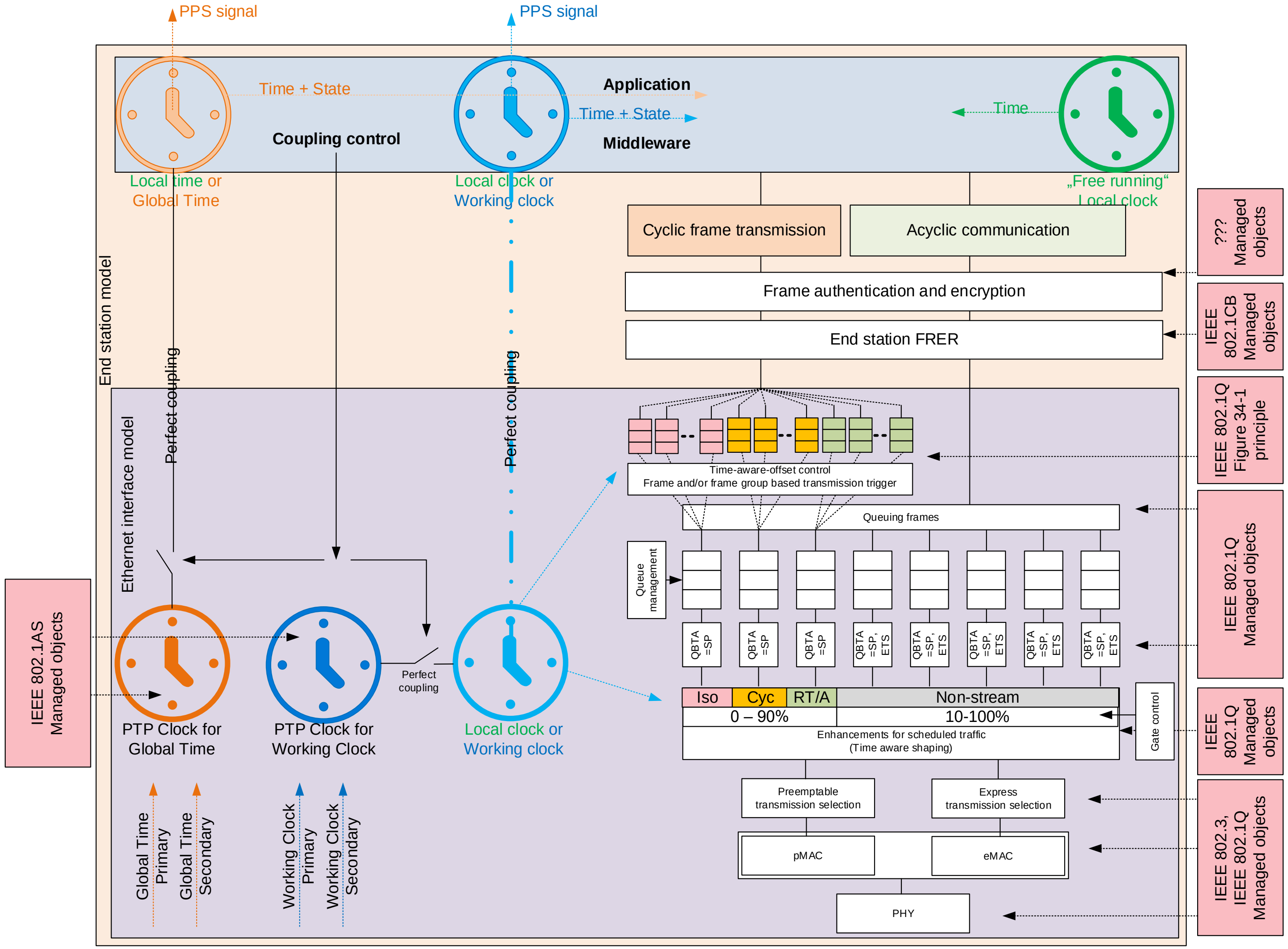


The three periodic traffic classes are shown in red, orange and green.

The five event-driven traffic classes are shown in grey.

Each vertical aligns its usage of the generic end station model based on its needs (often represented by the defined traffic classes)

Example including synchronization model



Working Clock is used to control

- [802.1Qcc] time-aware-offset
- [802.1Q] transmission gates

and

- Application based events which may need alignment between Ethernet interface and application

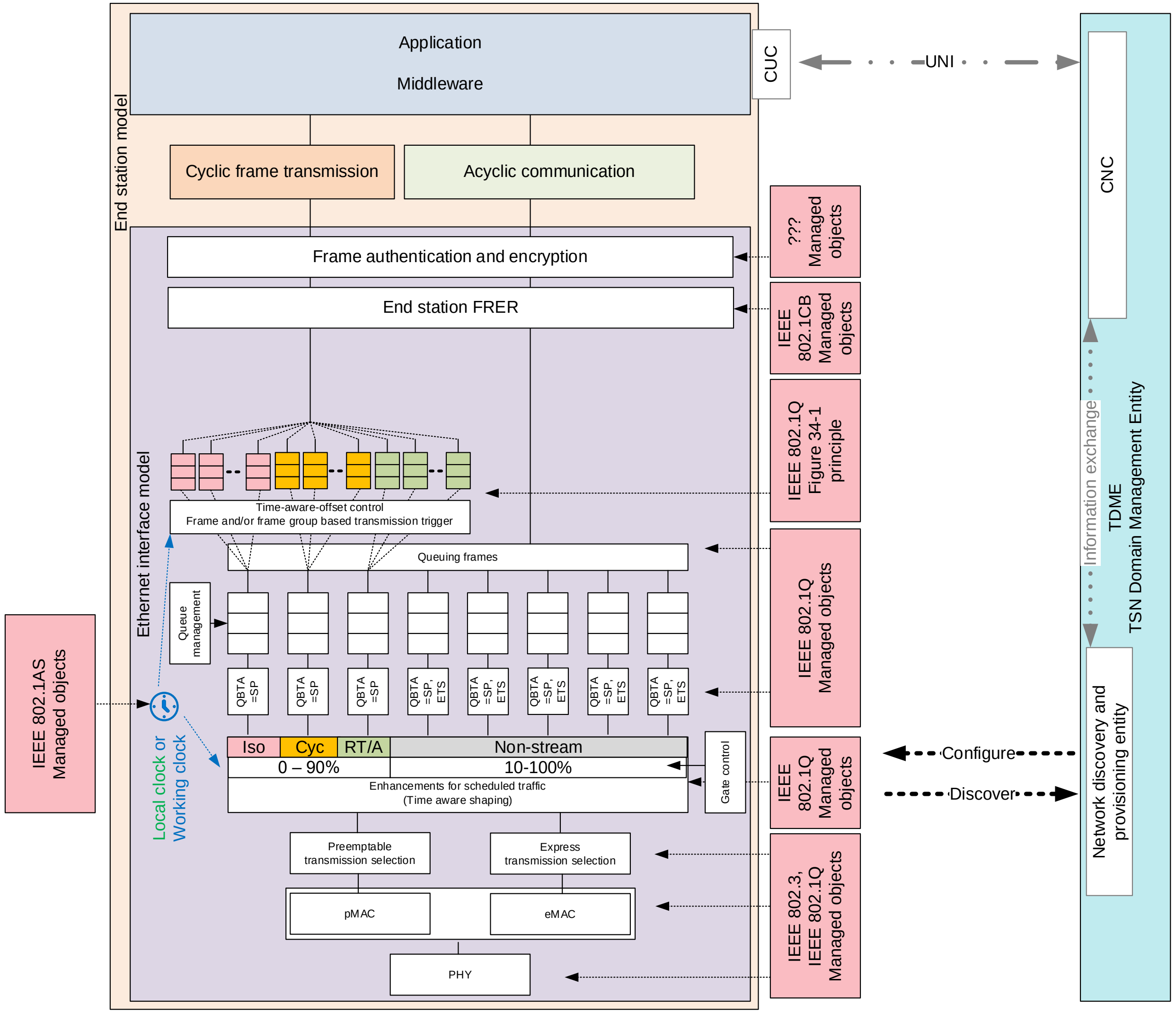
Global time is used to control

- Application based events and logs which may need e.g. plant wide alignment with other applications

Local time (strictly monotonic) is used for event which can not handle any jumps e.g. due to adjustment of rate or offset

Example for configuration

Example for configuration



TDME / CNC / Provisioning Entity is used to discover the end stations Ethernet interface features and to configure Ethernet interface.

This ensures convergence of the network configuration with the end station Ethernet configuration.

The discovery the Ethernet interface features allows the CNC to consider these information for the path and stream planning.

Conclusion

Proposal

- Specify an end station model covering requirements from many industrial automation verticals
- Functionalities of this model may be stated optional, but shall be specified in detail in the 60802
- Configuration of shown managed objects of the end station is done by network management of the TSN domain
- Principles shown in Figure 34-1 of 802.1Q may need additional text to cover the automation requirements

Questions ?