Deterministic Integration of Hard and Soft Real-Time Communication over Shared-Ethernet

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Outline

Outline

Elements

Assumed Distributed System

A set of nodes but only one communication bus (Ethernet)

Goals

Timeliness and Reliability of communication services

Local Resources

Carrier Sense ability, Clocks and Processing capacities

Constraints

No shared-memory, no centralized mechanism.

The solution: Protocols

Set of rules

- Organizes the MAC utilization

Shared knowledge

- MAC layer state $\in$ {idle, busy, jam}
- Message information (piggybacked)
- Timing information (synchronization)

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CSMA/CD

Carrier Sense Multiple Access with Collision Detection

Mechanisms

- Carrier Sense $\Rightarrow$ State Detection
- Jam $\Rightarrow$ Collision Detection

$\Rightarrow$ Shared Knowledge $\triangleq$ MAC state $\in$ {idle, busy, jam}

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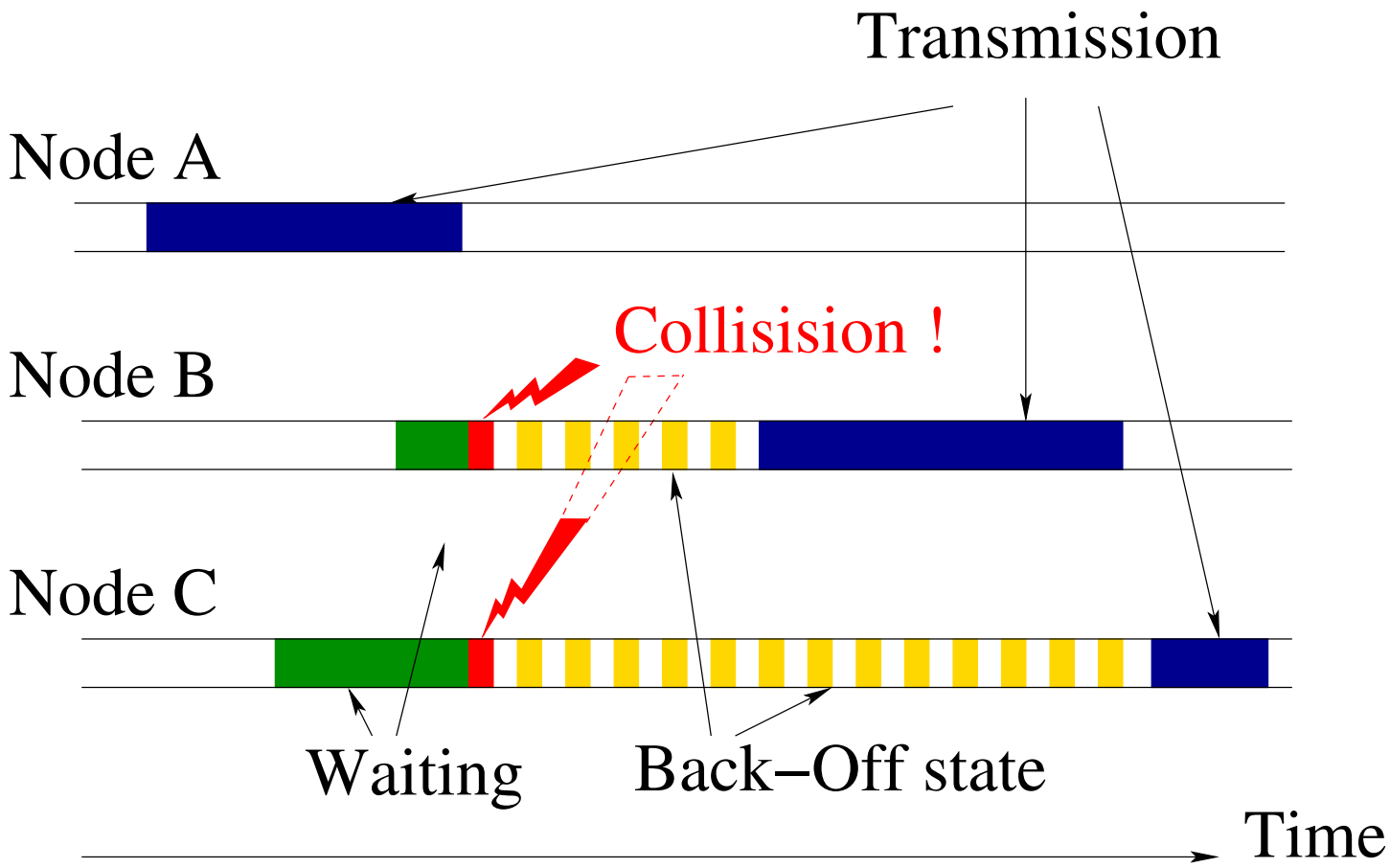
Protocol Outline

Node:

IF	***MAC = idle***	***THEN***	***transmit immediately***
IF	***MAC = busy***	***THEN***	***wait next EOF interrupt and transmit immediately***
IF	***MAC = jam***	***THEN***	***enter in Back-Off state for an aleatory time***

Waiting ⇒ Synchronization ⇒ Collision



Deterministic Ethernet Approaches

Hardware modification

- Priority Reservation by Interruption, modification of Jam message...

Switch Ethernet

- Utilization of point-to-point communication channel
- Time delays in the switchs, Possible message loss, Broadcast communication less efficient

Master / Slave (FTT)

- The master allocates bandwidth to the slaves using triggering messages
- Centralized solution, message overhead

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TDMA Time Division Multiple Access

- For each communication period, each nodes has a slot time to transmit
- Synchronization of local clocks, waste of the bandwidth

Token Ring

- An explicit token rotates between the nodes, allowing the nodes transmission (scheduling possibilities)
- Token overhead, token loss, significant variability between best case and worst case

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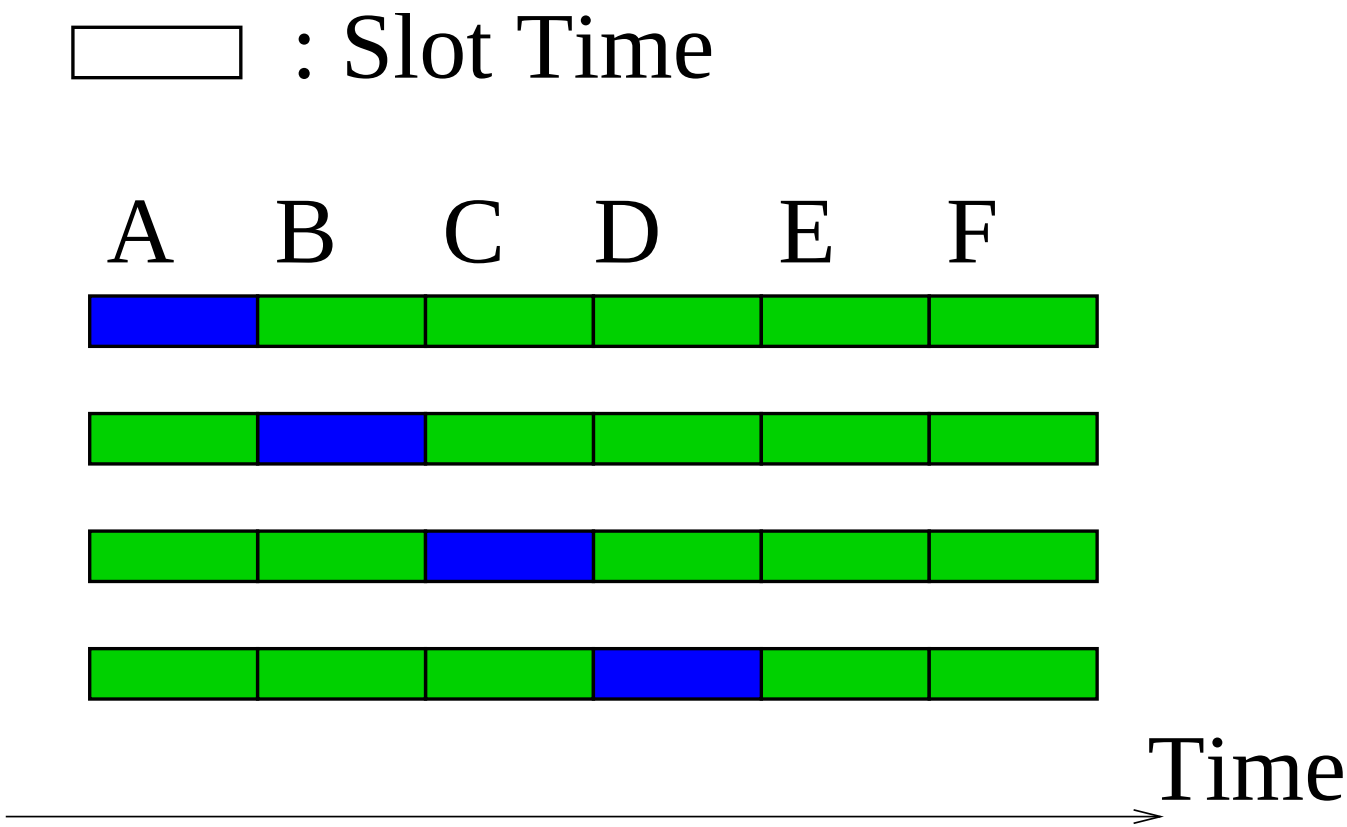
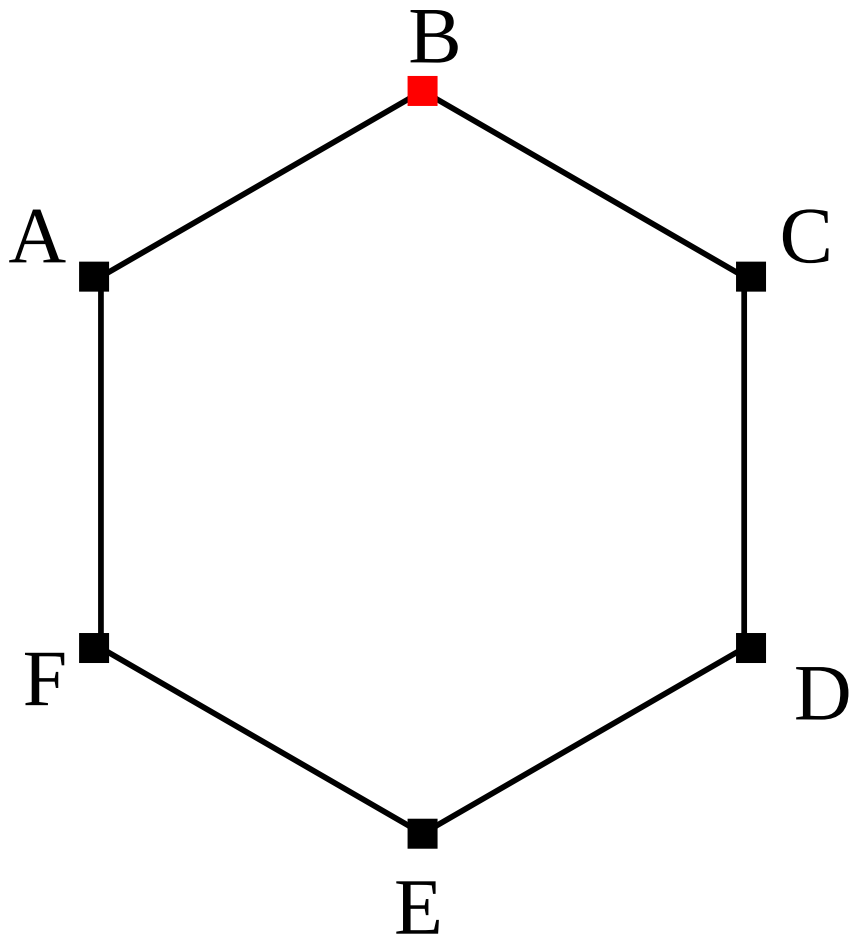
TDMA Approach



Token Ring Approach



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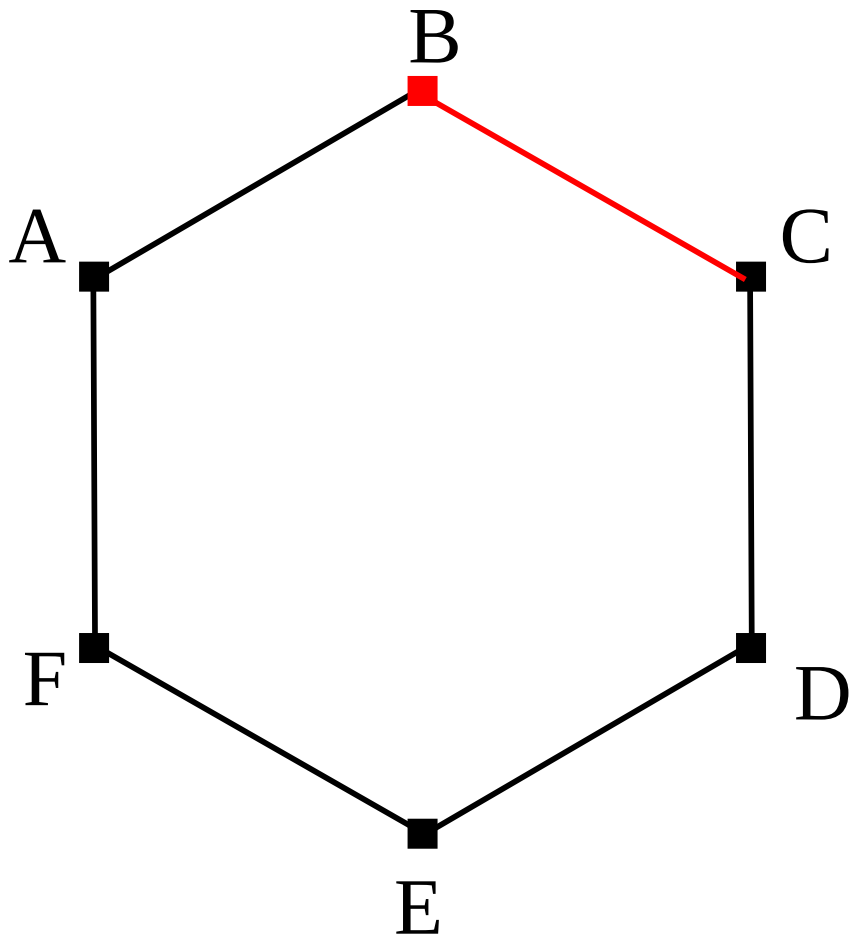

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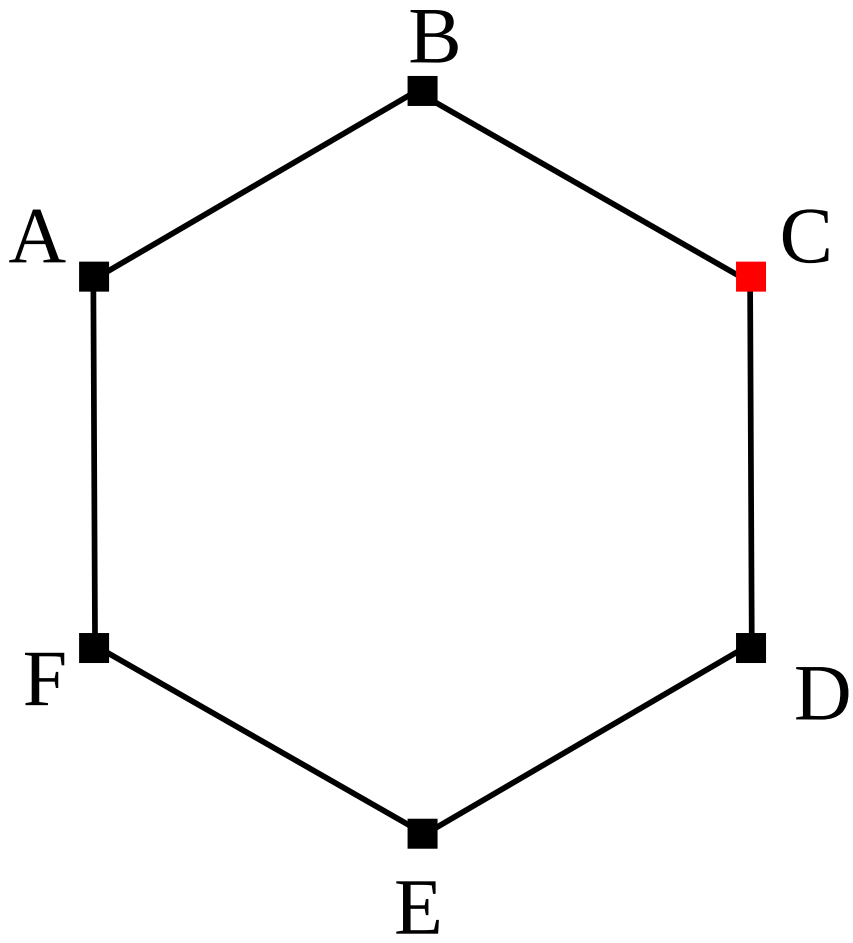
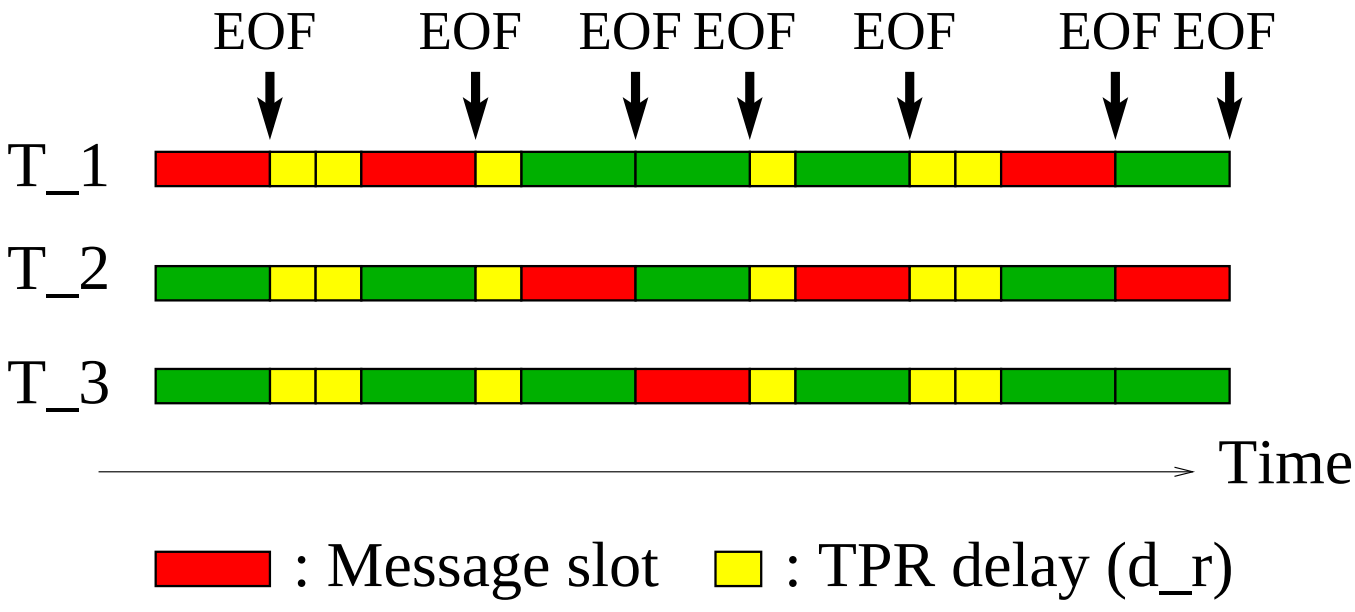


Deterministic Ethernet Approaches

Virtual Token Ring

- An implicit token rotates between the nodes, allowing the nodes transmission according to temporal rules
- No token overhead and token loss, significant variability between best case and worst case

TPR Mechanism



Outline

Hybrid Systems

Hard Real Time

Controlled jitter and bounded message transmission time

Soft Real Time

Firm deadline, High throughput, Non-periodic tasks

Specialities

- Integration of Hard and Soft communications
- Deterministic service for real-time applications
- Flexible service for soft communication

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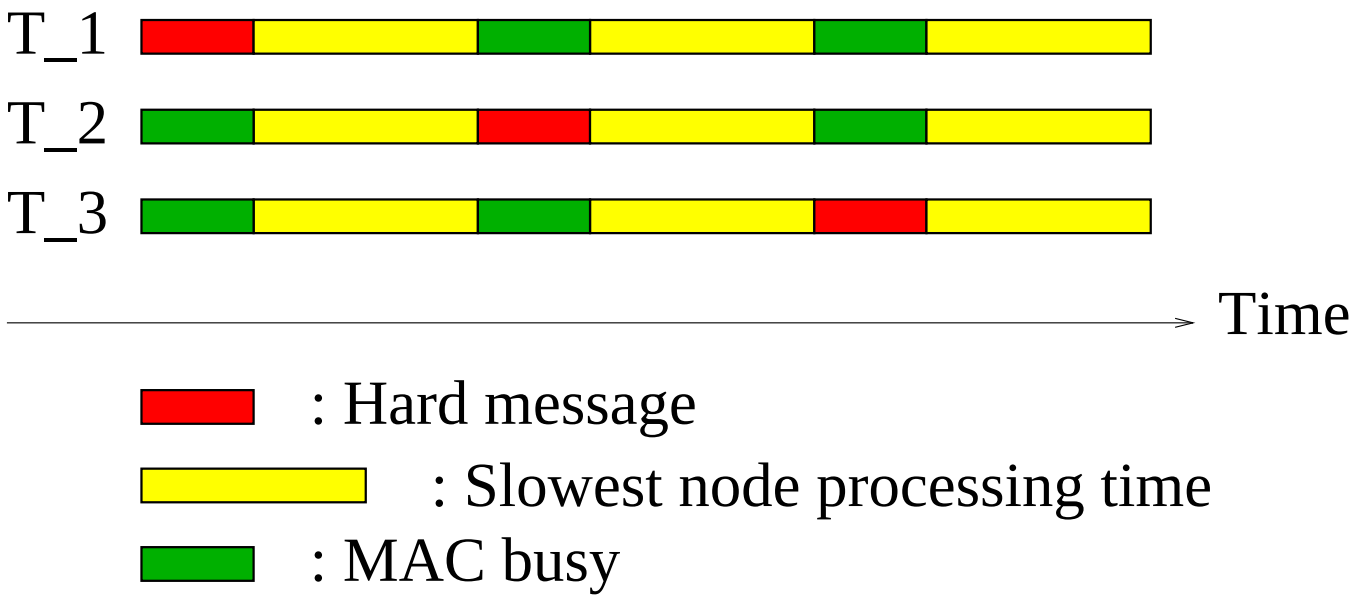
The Processing Time Delay



Hybrid Systems

Constraints

- Isolation of Hard and Soft communication
- Hard message processing delays (slow nodes)
- High throughput for soft communication

Elements of Solutions

- TDMA
- Interleaving of Hard and Soft messages
- Virtual Token Scheme for Soft communication

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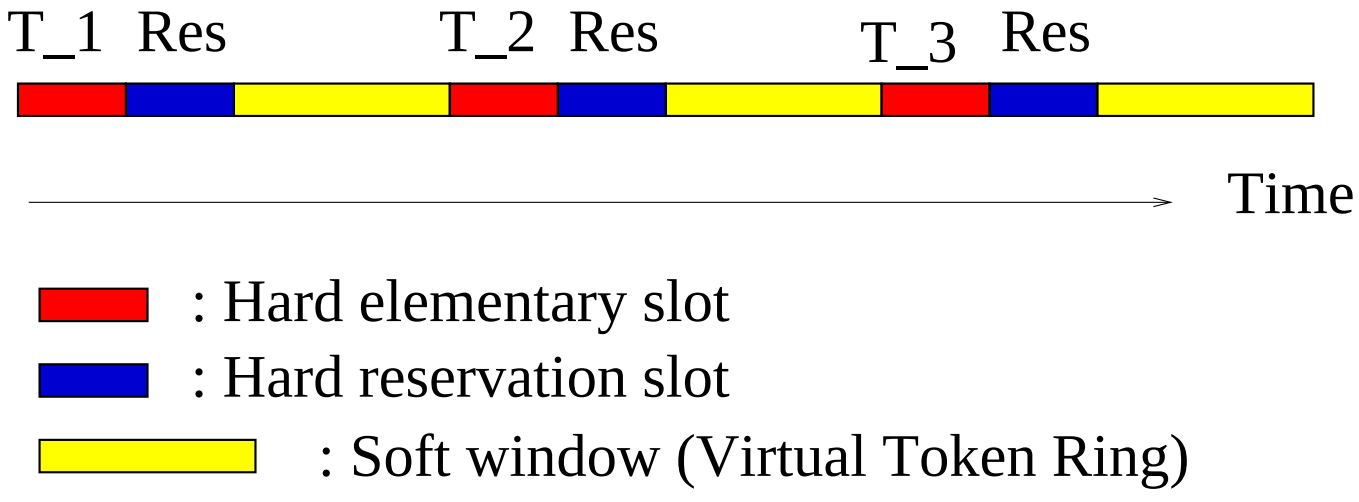
DoRiS
Double Ring Service

Computation Model

- Ring of tasks: $R^H = \{T_1, T_2, \ldots, T_{N_H}\}$
- Ring of processes: $R^S = \{P_1, P_2, \ldots, P_{N_S}\}$
- Size of hard message = 64B
- π : maximum processing time of hard messages
- Publish-Subscribe communication model

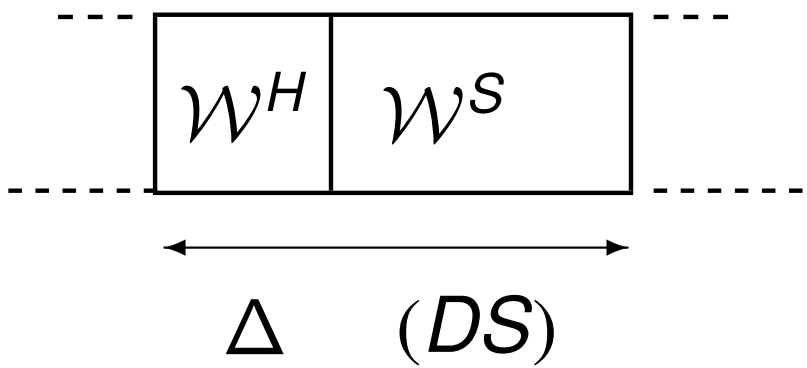
DoRiS: The Double Ring Structure



DoRiS
Double Ring Service

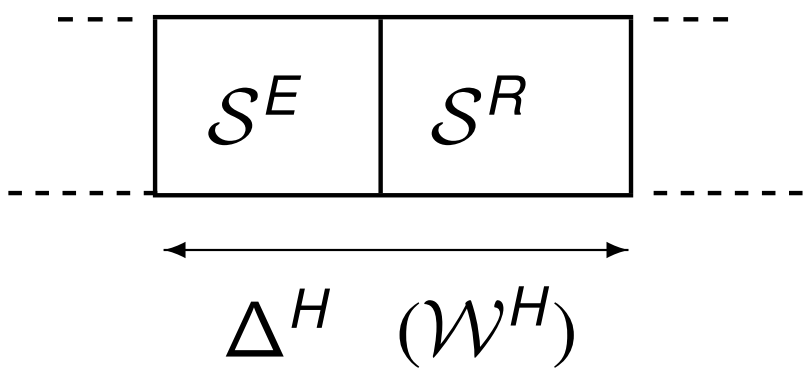
The Hard Real-Time Ring R^H

- *DoRiS Segments* (DS_k for $k \in \mathbb{N}^*$) of size Δ
- Hard Window $\mathcal{W}_k^H$
- Soft Window $\mathcal{W}_k^S$



The Hard Real-Time Ring R^H

- Each Hard Window $\mathcal{W}_k^H$ is divided in two slots
- Elementary Slot $\mathcal{S}_k^E$
- Reservation Slot $\mathcal{S}_k^R$
- The slot size is δ (transmission time of 64B)



DoRiS
Double Ring Service

Fundamental property

- Elementary Messages are mandatory: Each task sent one elementary message per *DoRiS* rotating sequence (*RS*)

Consequences

- Pulse Decentralization
- Periodicity ⇒ Determinism
- Local clocks synchronization ⇒ Reliability

Other properties

- Reservation mechanism ⇒ Flexibility

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The Soft Ring R^S

- A Soft Window $\mathcal{W}_k^S$ implements temporal rules using local timers
- A virtual token rotates between processes according to temporal rules
- Elementary messages serve as pulses
- Time Packet Release Mechanism of parameter d_r
- STOP mechanism $\Rightarrow$ Fairness
- The maximum soft message size is 1518B

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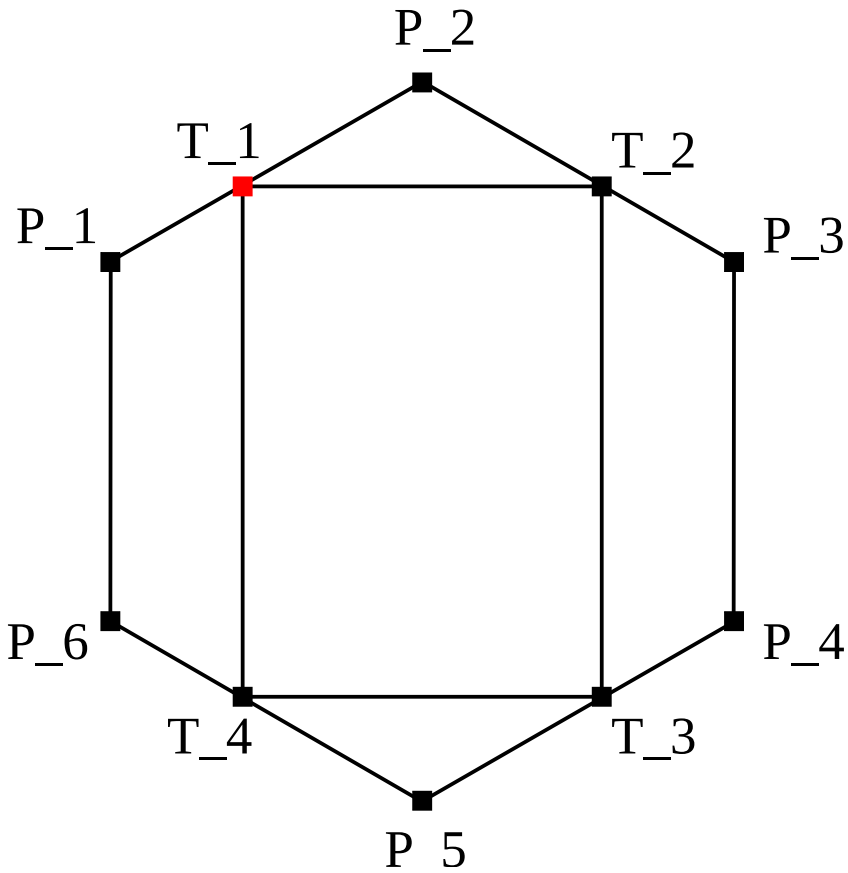

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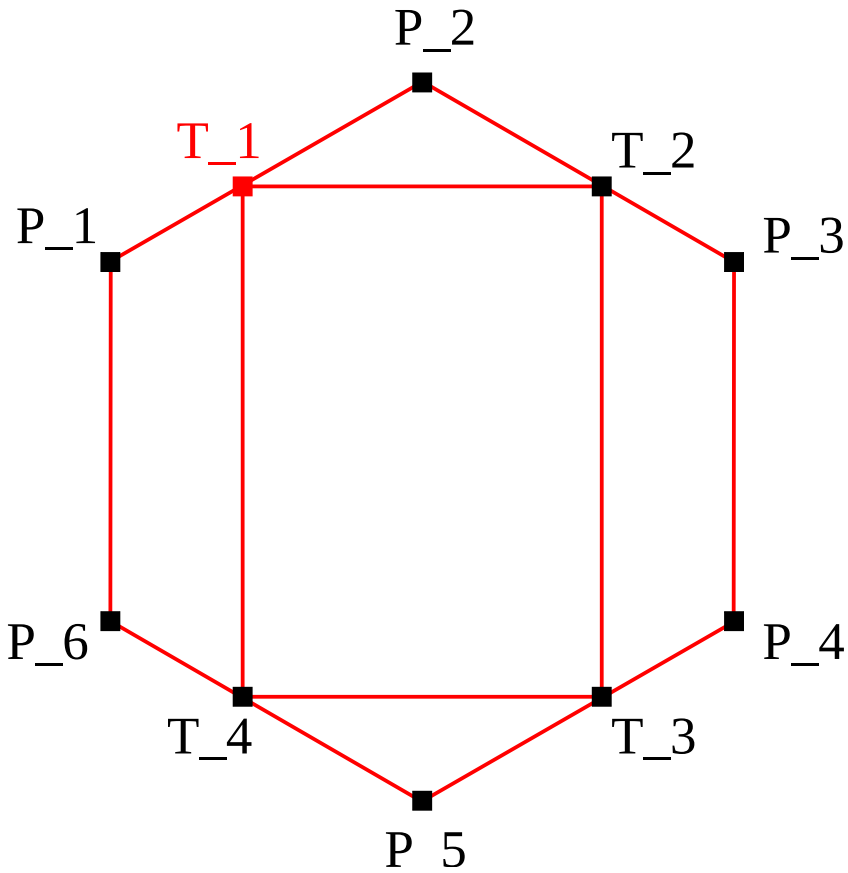

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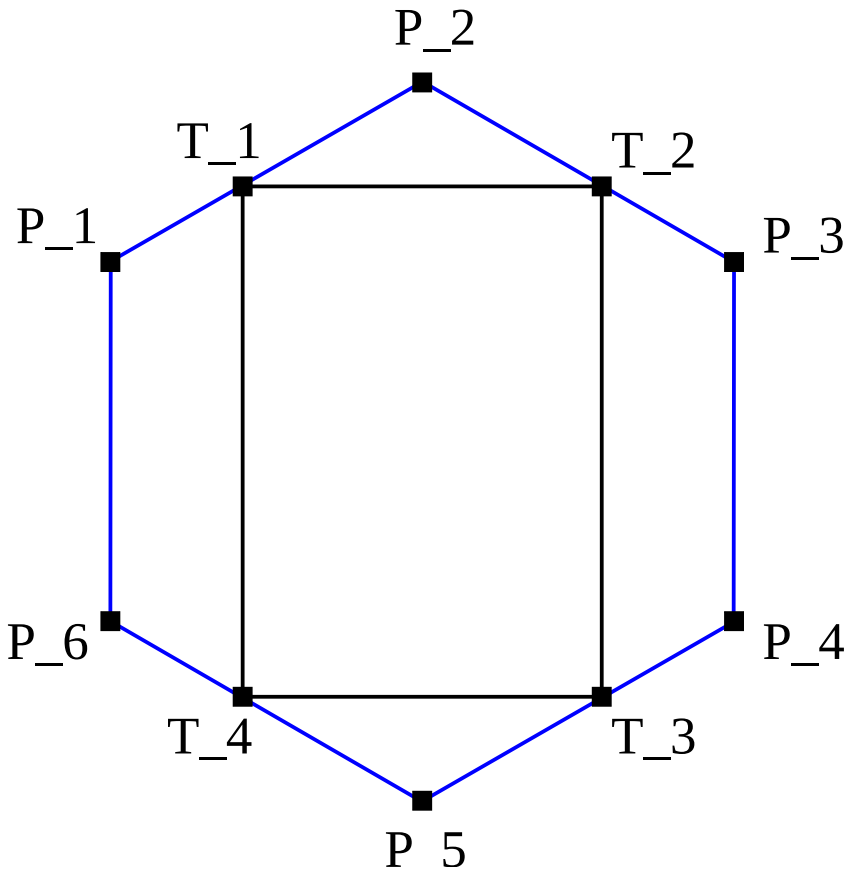

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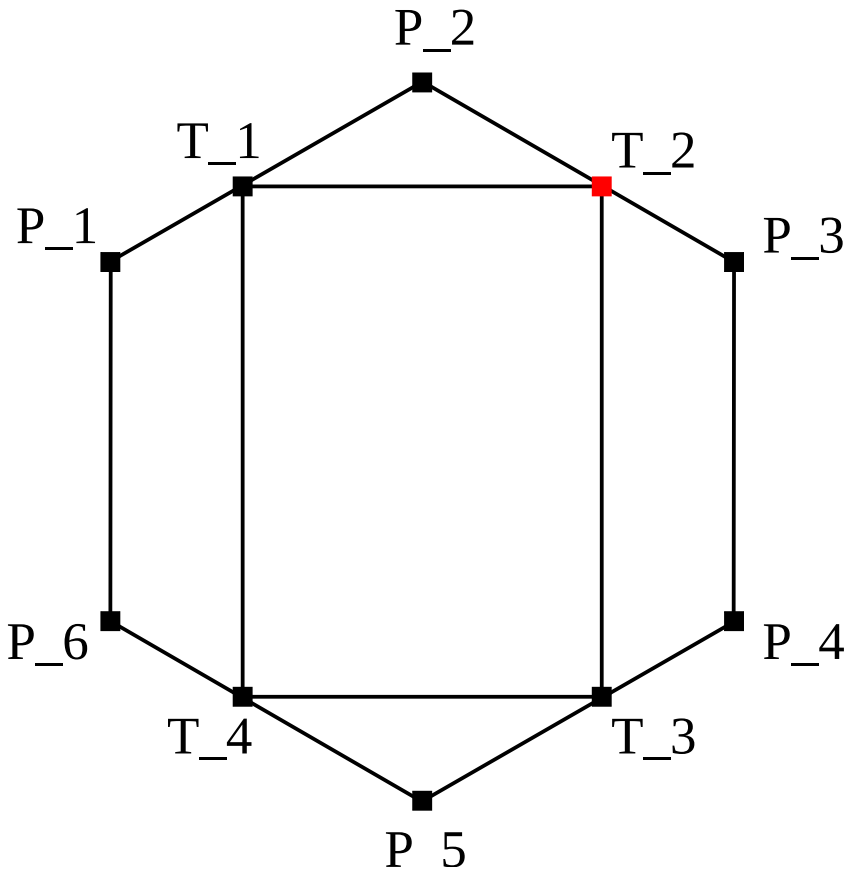

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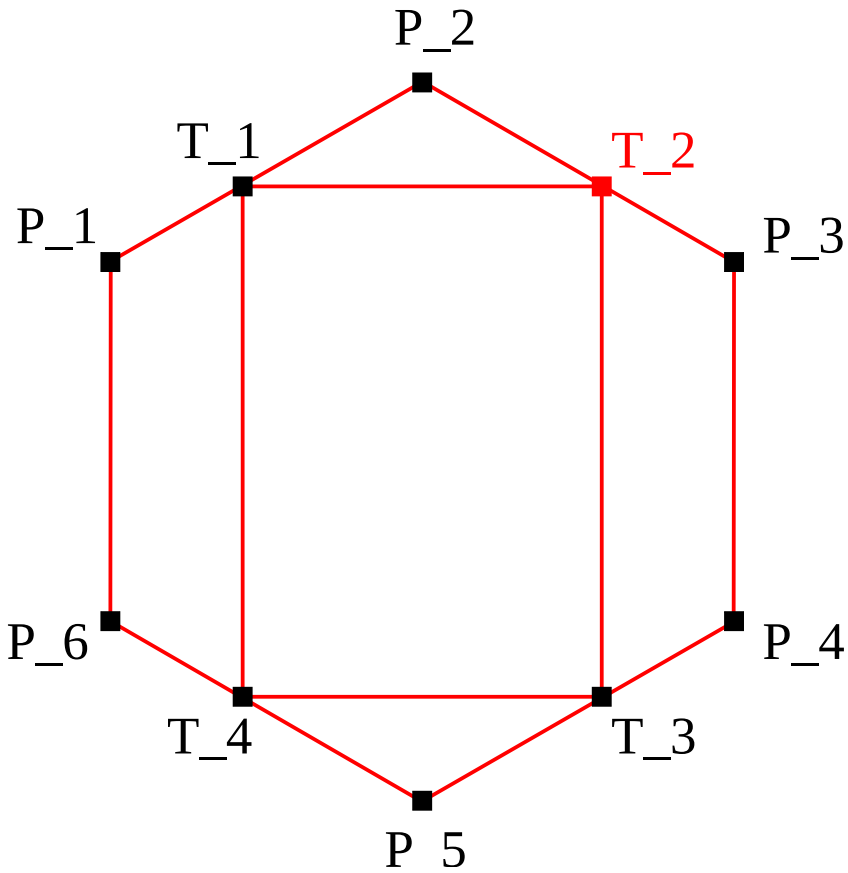

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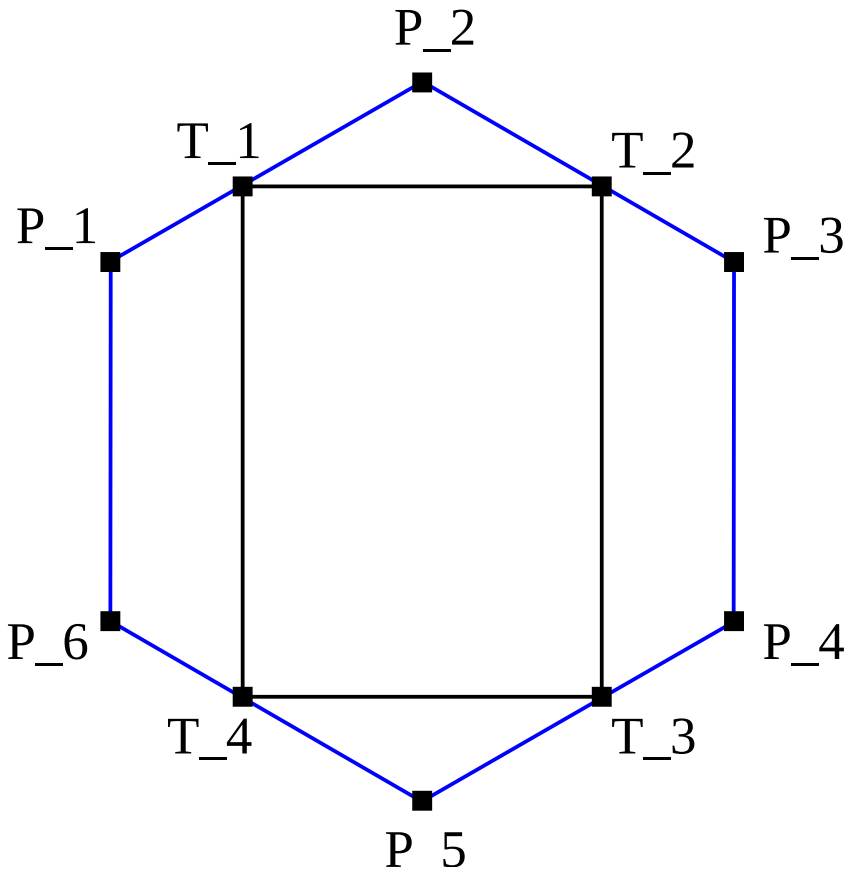

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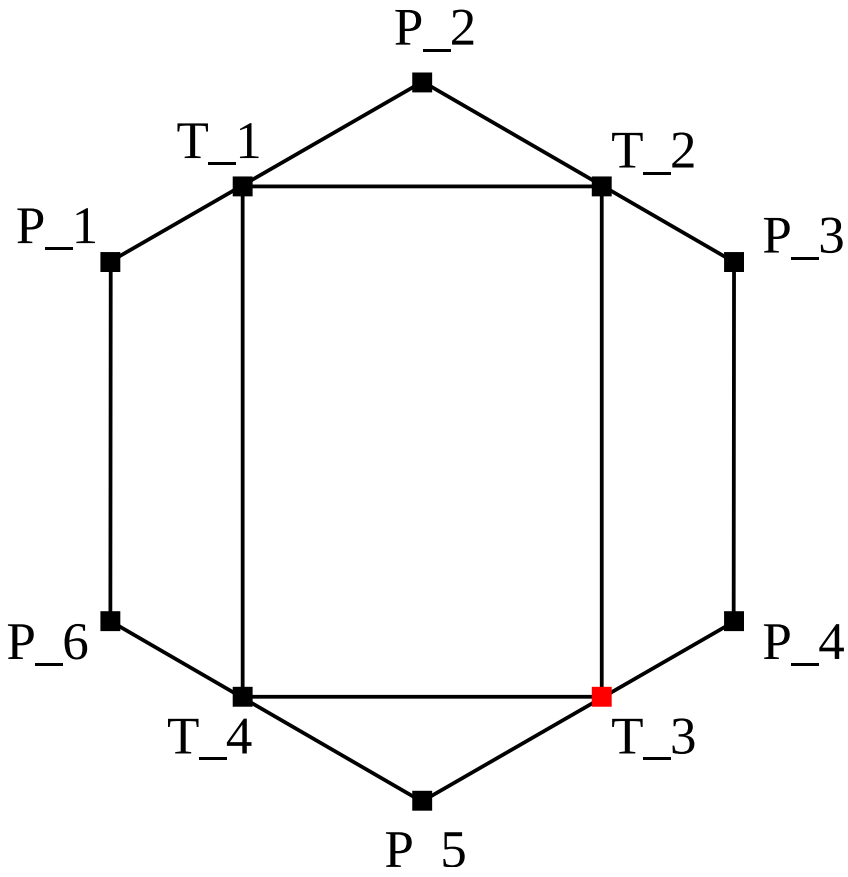

DoRiS
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Reservation Mechanism

- An Elementary Message carry a reservation list
- A task can only reserve free slots of the next *DoRiS* rotating sequence
- There is always at least one free slot

Fault Tolerance Mechanism

- A task can only reserve if it received all elementary messages sent in the previous *DoRiS* rotating sequence

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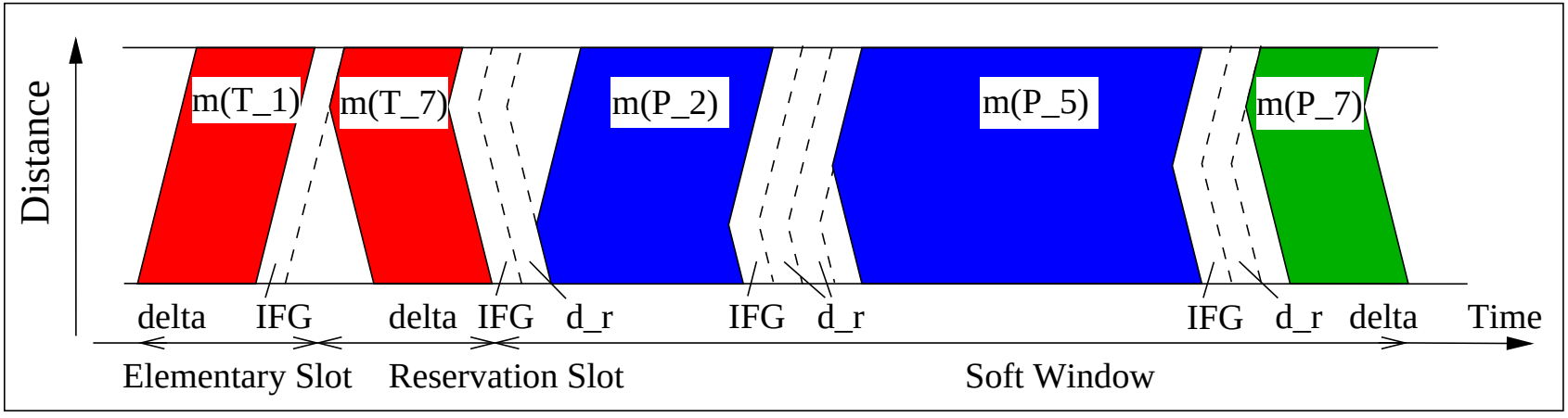
A *DoRiS* segment



Summary

- The CSMA/CD protocol over Shared-Ethernet is not deterministic .
- The *DoRiS* protocol mixed TDMA and Virtual Token approaches to turn Shared-Ethernet Deterministic, providing high throughput for soft task.

- Future works
  - Membership control, dynamic reconfiguration
  - Formal specification with TLA+

For Further Reading I

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