Data plane Enhancement Taxonomy

draft-ietf-detnet-dataplane-taxonomy-04

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History of Taxonomy draft

- Started as the Chair's request to categorize the data plane solutions.
- Defined One performance-related categorization & Four functional categorization criteria.
- Specified seven Suitable categories.
- Specified two Reference network topologies.

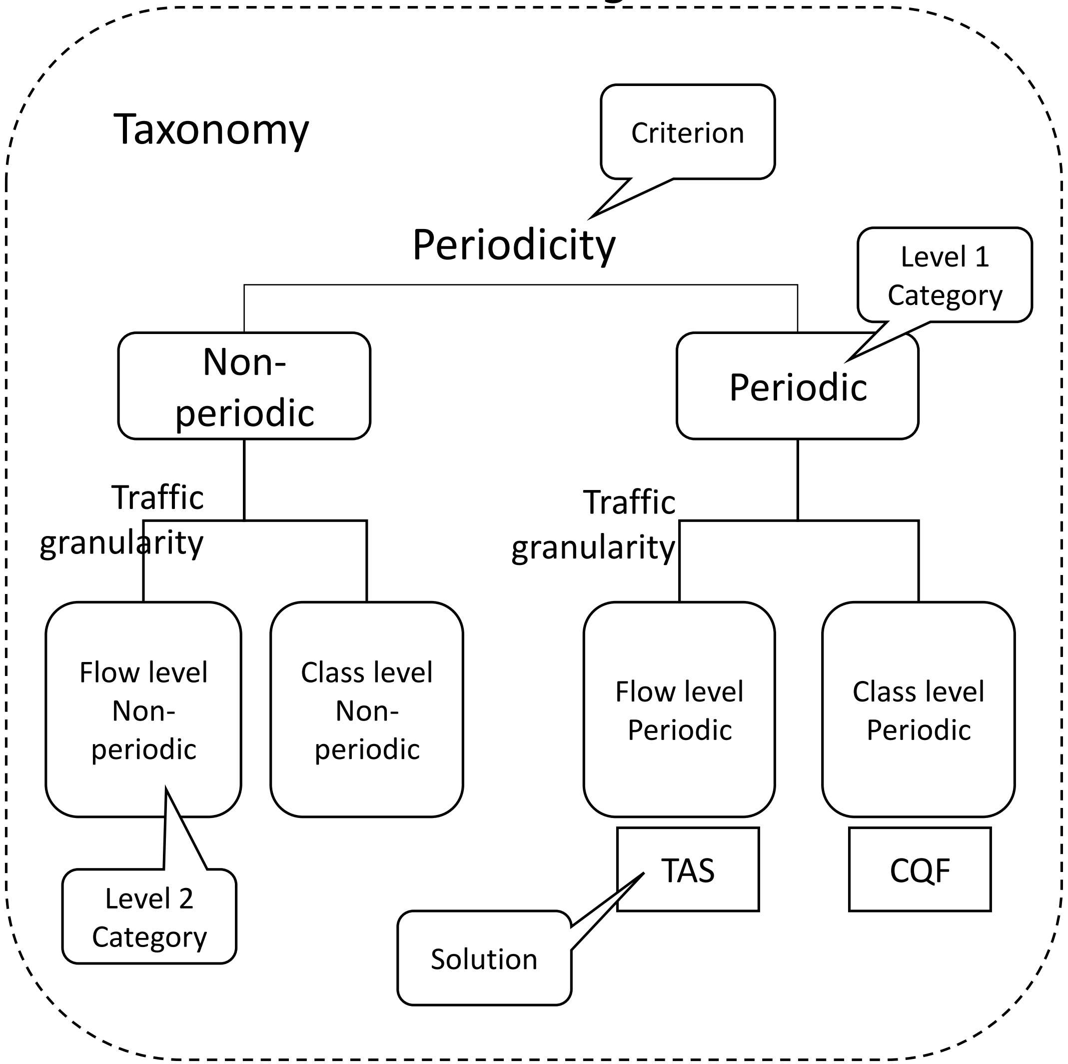
Overview of the draft

- Purpose
  - To facilitate the understanding of the data plane enhancement solutions, which are suggested currently or can be suggested in the future, for deterministic networking
- Scope: to provide
  - criteria for classifying data plane solutions
  - examples of each category, along with reasons where necessary
  - strengths and limitations of the categories
  - suitability of the solutions for various services of deterministic networking
- Out of scope
  - The candidate solutions currently being proposed in DetNet WG are simply listed without any descriptions. The details of the solutions are intentionally omitted.

Definitions of terminologies

- **solution**: A set of data plane functional entities, such as queue, scheduler, and regulator; which can guarantee a certain level of latency and jitter performance to a flow
- **taxonomy**: A systematic method by which a solution is put into a category
- **category**: A set of solutions that is put together by one or more criteria
- **criterion**: A principle or standard by which a solution can be judged or decided to be put into a certain category
- **level of category**: The number of criteria that are used to determine a category
- **suitable category**: A category within which solutions can be suitable for deterministic networking

Illustration for terminologies



Document structure

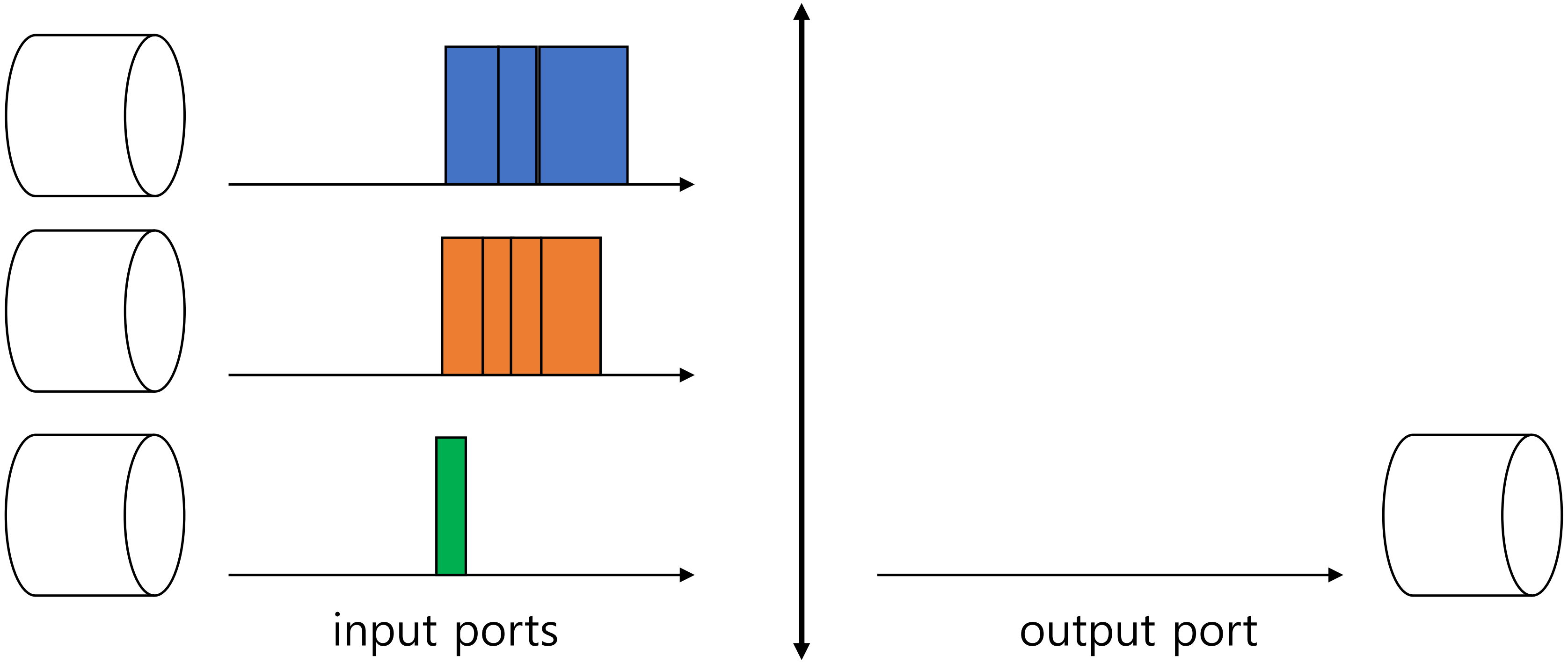
Today's focus

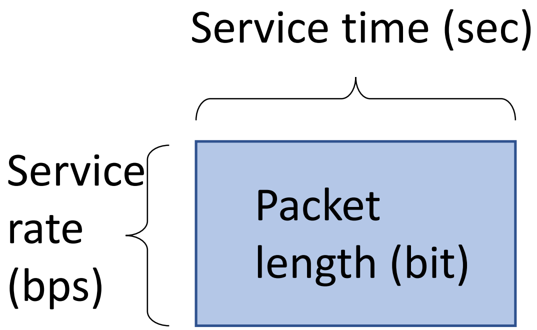
Criteria for taxonomy

Criterion		Categories (Level 1)			
Per Hop Dominant Factor for E2E Latency Bound	What is the dominant term in the mathematical expression for latency bound per hop?	Max Packet Length / Service Rate	Sum of Max Packet Lengths / Link Capacity	Sum of Max Burst Sizes / Link Capacity	
Periodicity	Does the solution have a periodic pattern of transmitting packets?	Periodic		Non-periodic	
Traffic Granularity	How fine (or coarse) the traffic is treated?	Flow level (Flow aggregate level)		Class level	
Time bounds	Does a packet have specific time(s) for transmission completion allowed?	Unbounded	Right-bounded (with a latest allowed time)	Left-bounded (with an earliest allowed time)	Bounded (with both)
Service Order	What is the primary decision factor for packet transmission order?	Rate-based	Time-based (e.g. deadline)	Arrival-based	Priority-based

Taxonomy with performance: Per Hop Dominant Factor for Latency Bound

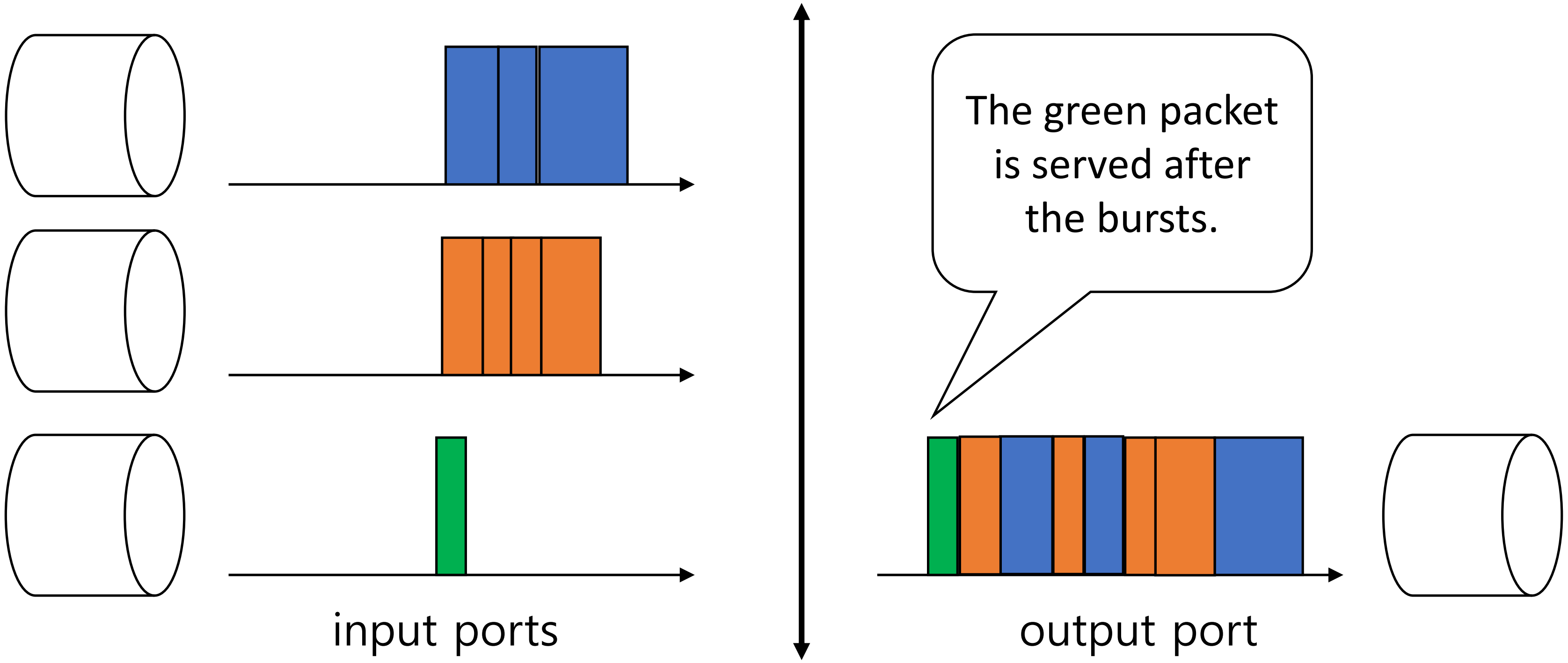
- Three flows arrive from different input ports. Two of them are bursty.
- How will the green packet, which arrived after these bursts, be scheduled?

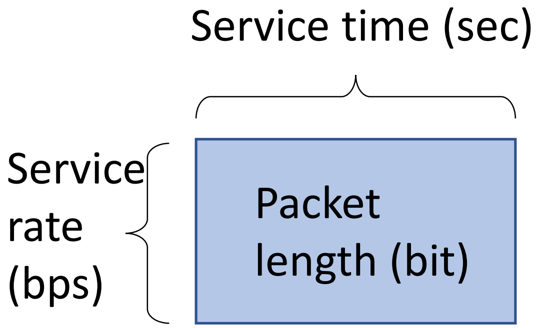




Taxonomy with performance: Per Hop Dominant Factor for Latency Bound

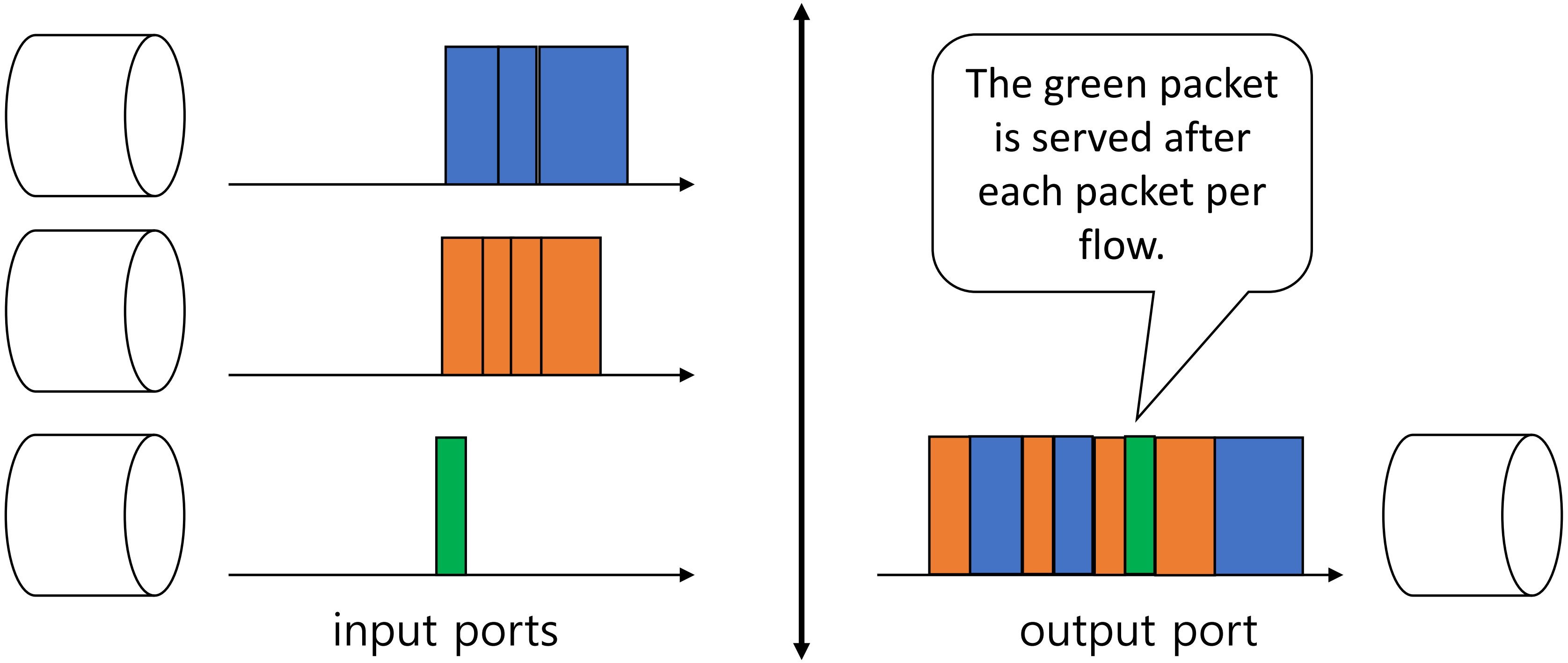
- First case: The green packet is served after the bursts from the other flows.
- The latency is affected by the sum of the max burst sizes. Example: FIFO scheduler

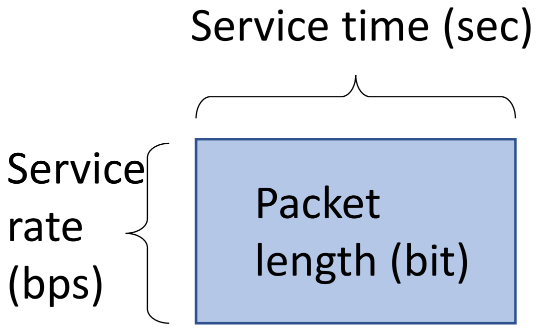




Taxonomy with performance: Per Hop Dominant Factor for Latency Bound

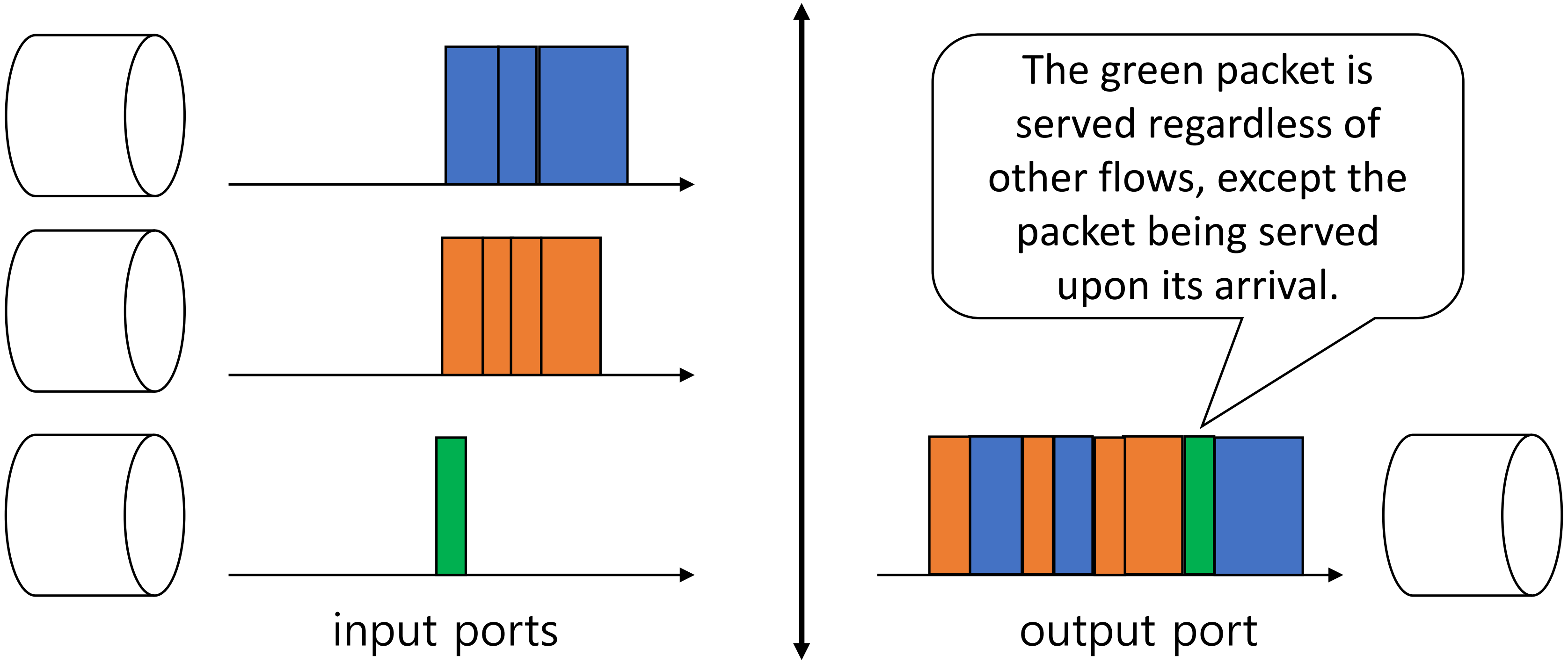
- Second case: After each packet per flow
- The latency is affected by the sum of the max packet lengths of flows. Example: Round robin scheduler

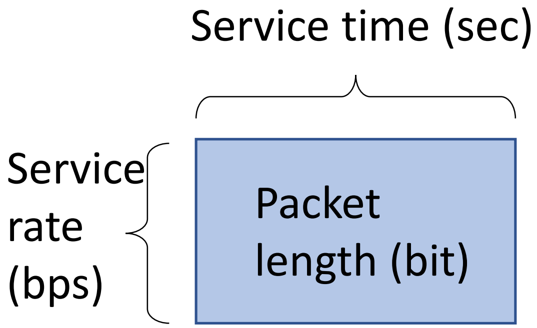




Taxonomy with performance: Per Hop Dominant Factor for Latency Bound

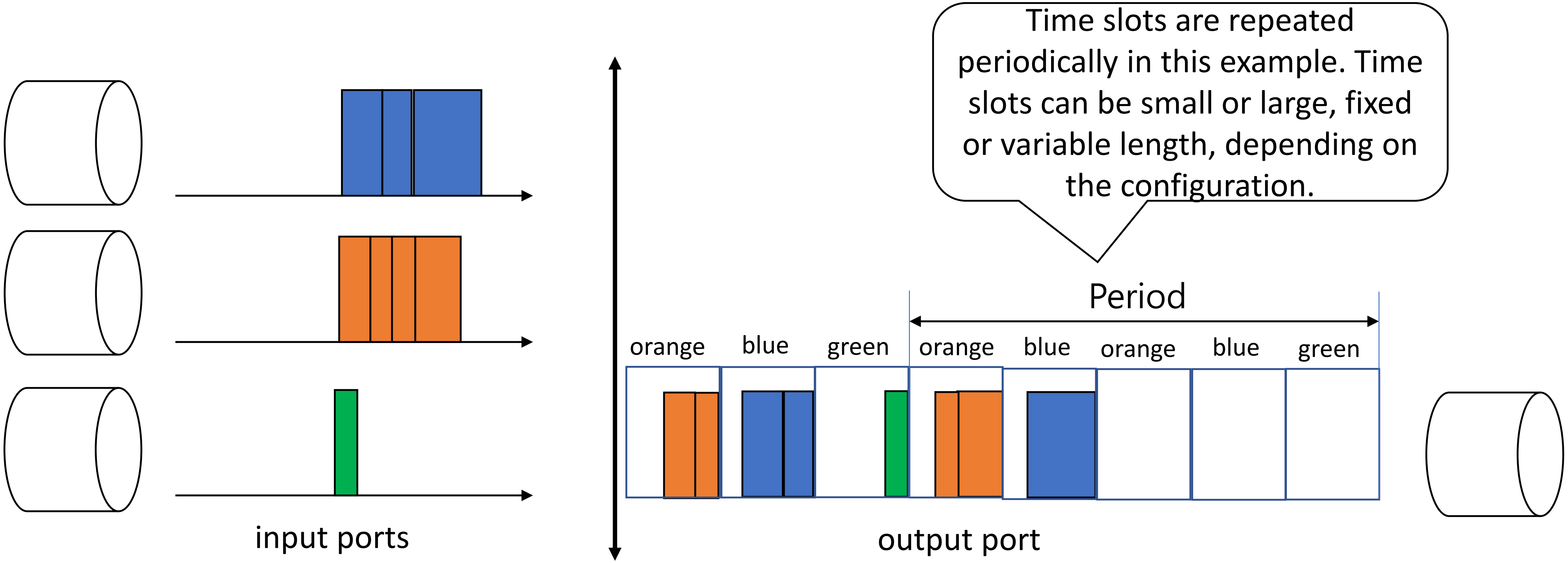
- Third case: Expedited by some means, the green packet is serviced after the current packet.
- The latency is affected by the maximum packet length in the link.





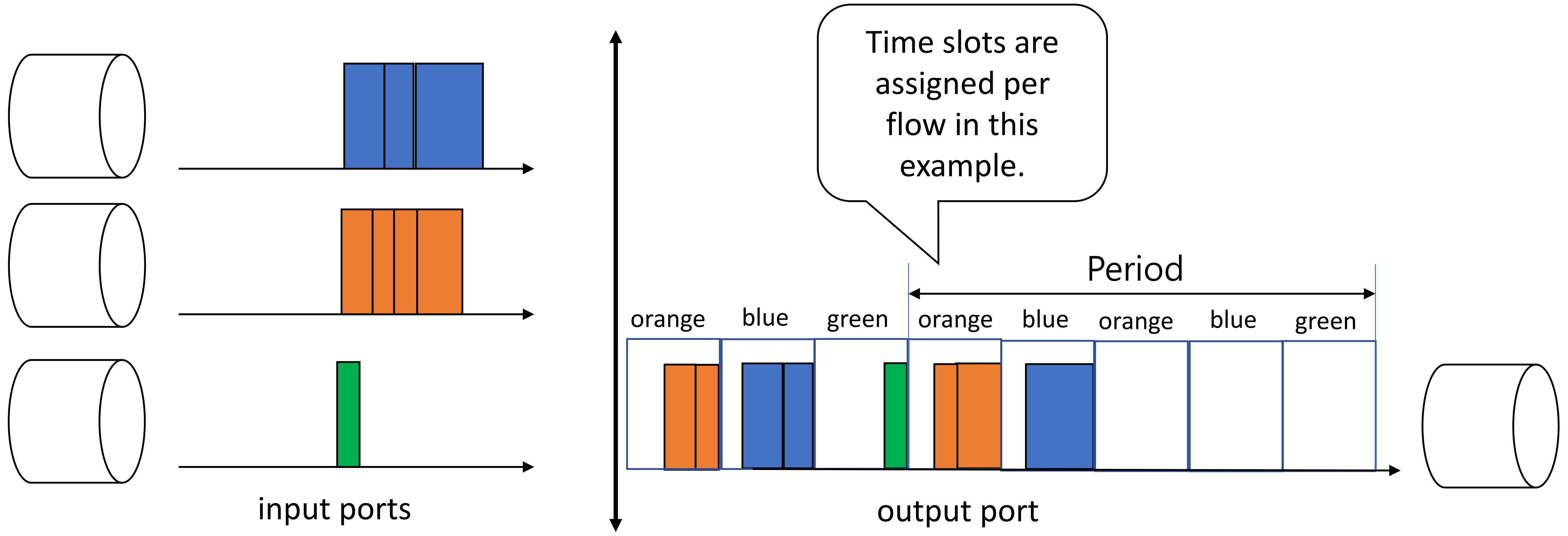
Taxonomy with function:
1. Periodicity

- Periodic: Packets are scheduled with a periodic pattern of time slots



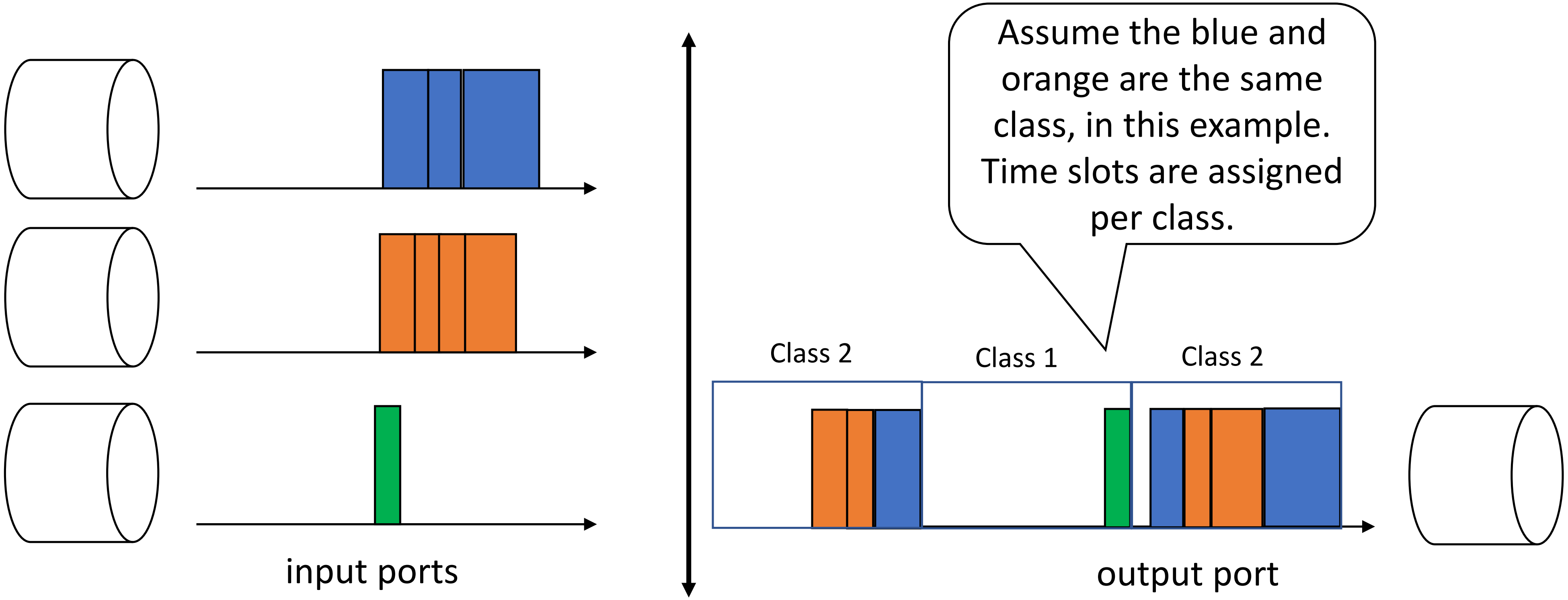
Taxonomy with function:
2. Traffic granularity

- Flow level: Each packet is controlled based on its specific flow



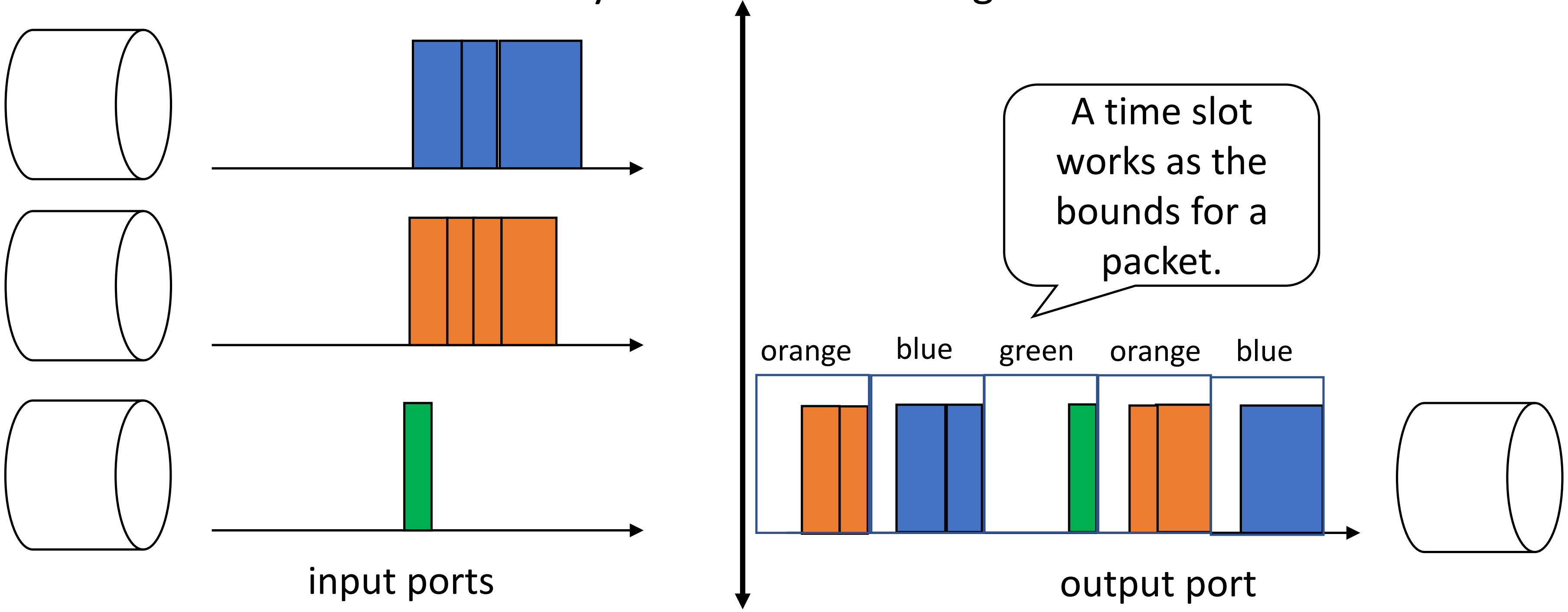
Taxonomy with function:
2. Traffic granularity

- Class level: Each packet is controlled based on its class



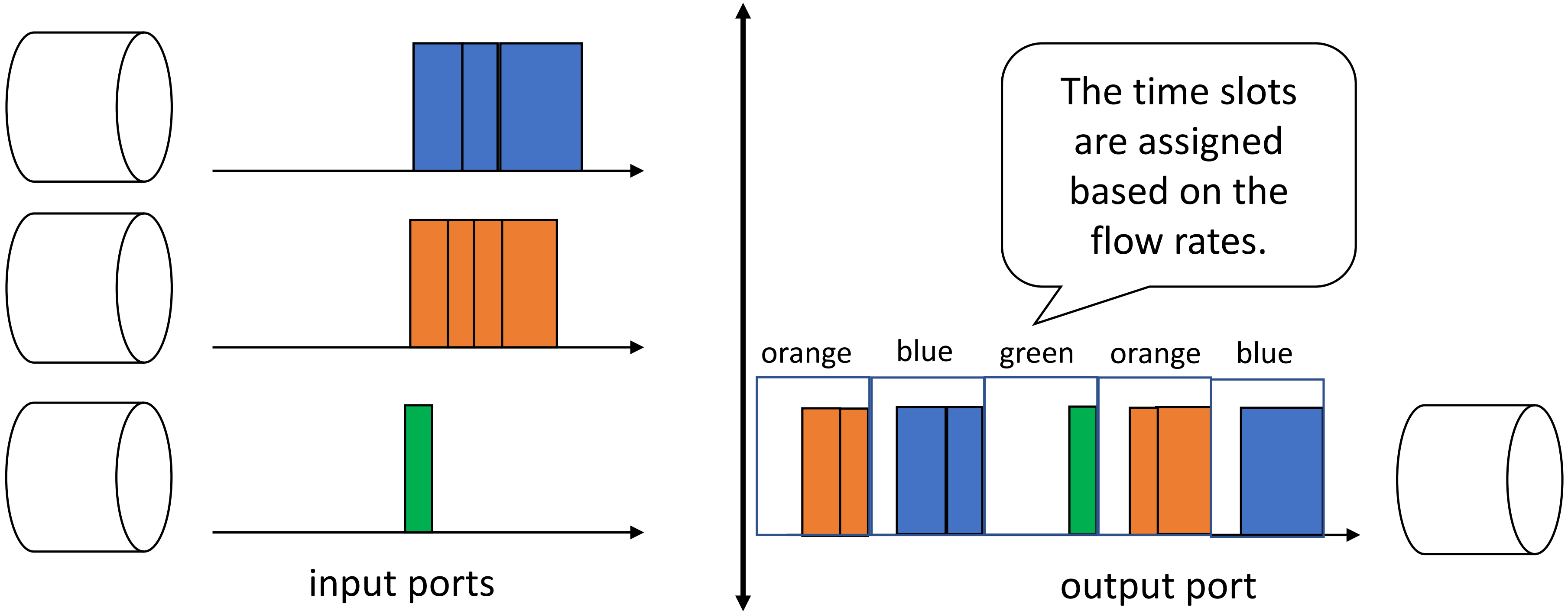
Taxonomy with function:
3. Time bounds

- Bounded: A packet has both an earliest and a latest time allowed for transmission completion.
- In the example below, a time slot for the green packet works as these bounds.
- A solution can have only a left-bound or a right-bound.

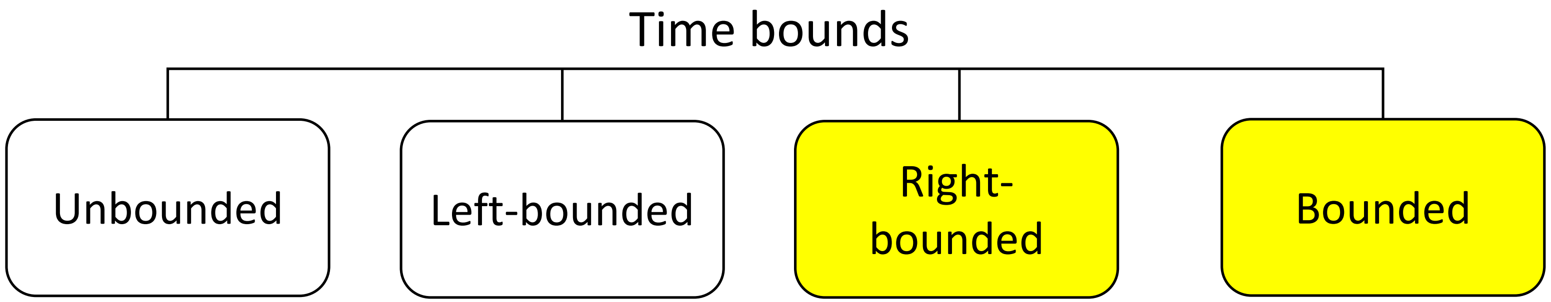


Taxonomy with function:
4. Service order

- Rate-based, Arrival-based, or Priority-based: Packets are ordered based on the allocated service rates, their arrival, their priorities, or a combination of three.
- In the example below, the time slots are assigned for flows, and are based on their service rate.

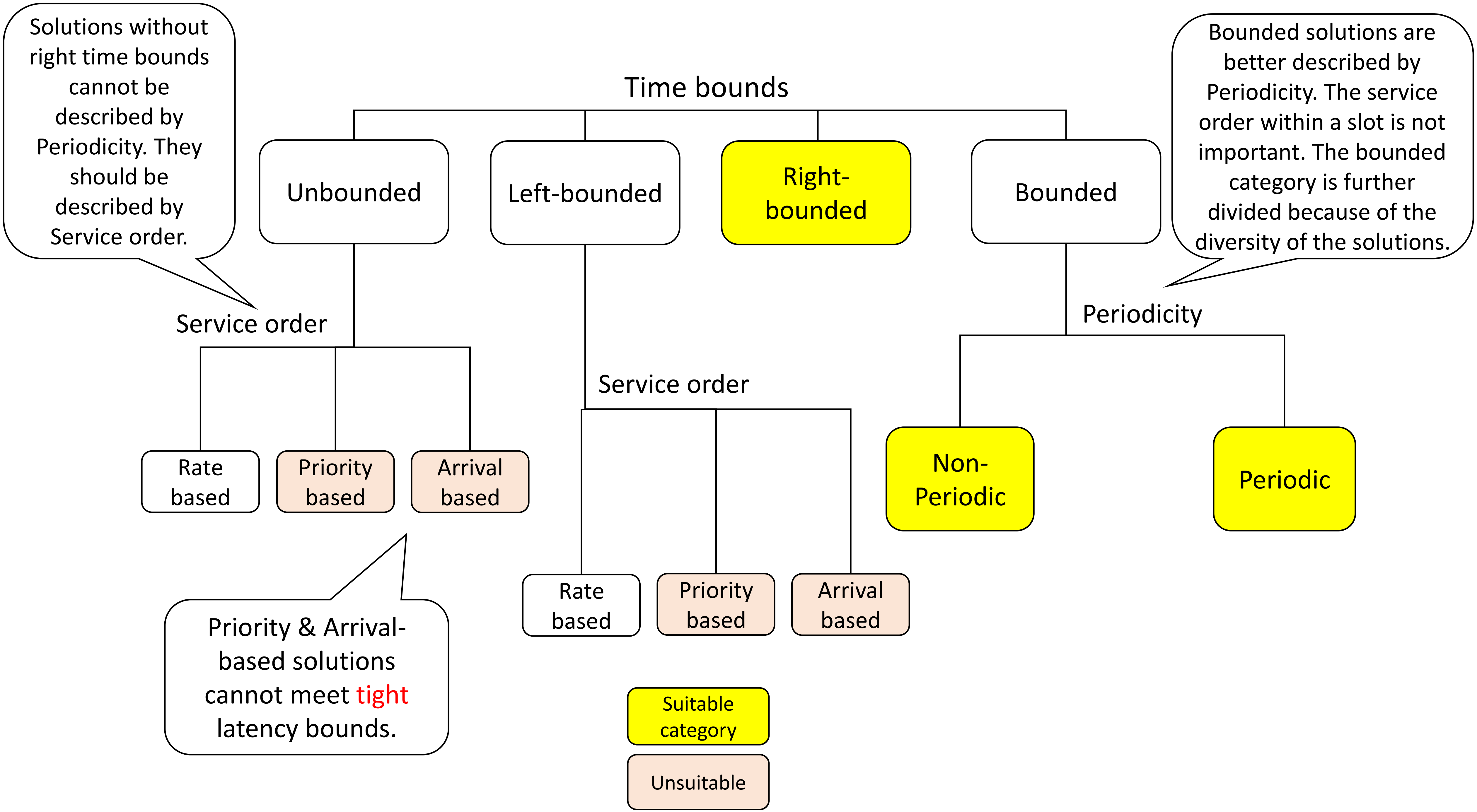


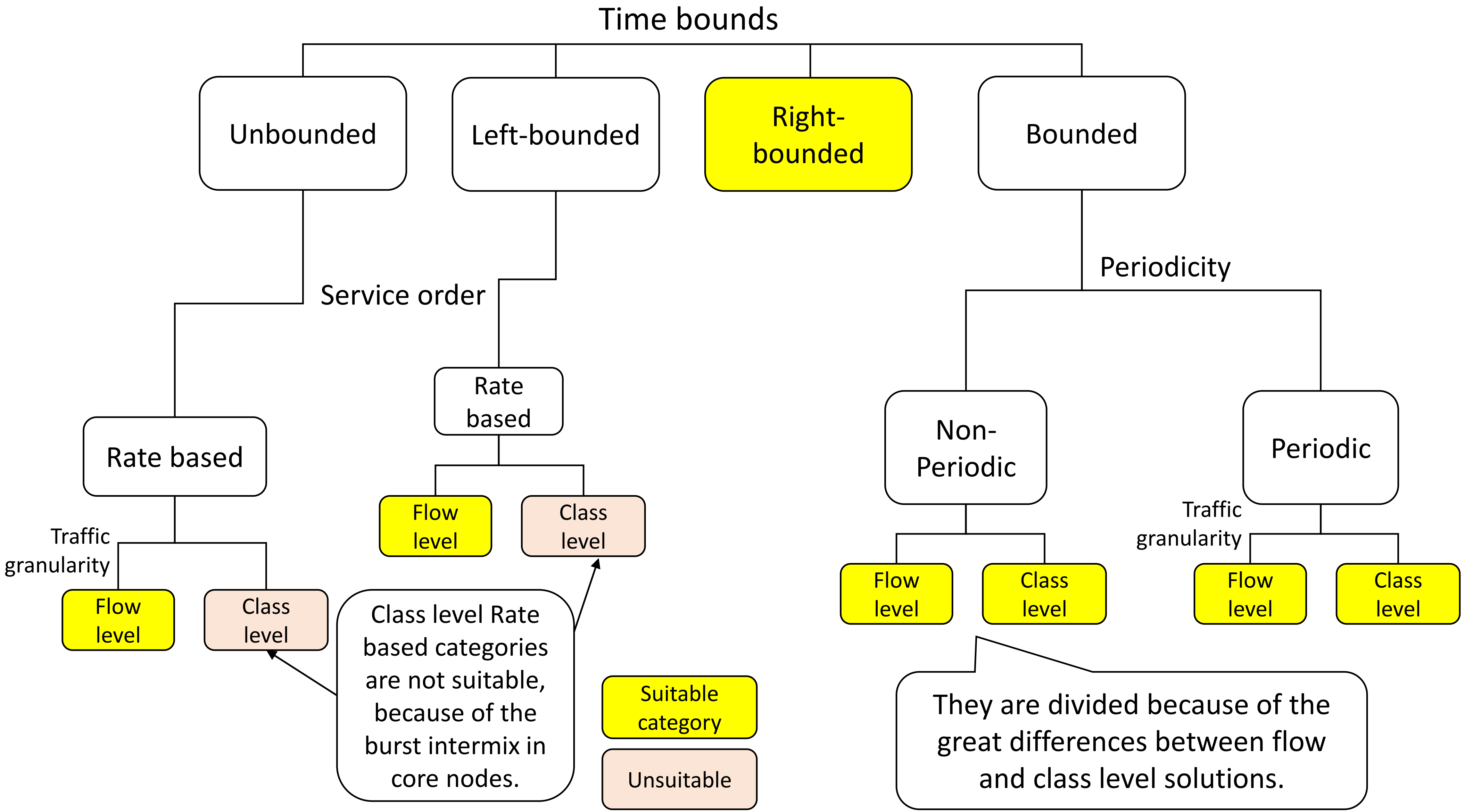
Suitable categories for DetNet



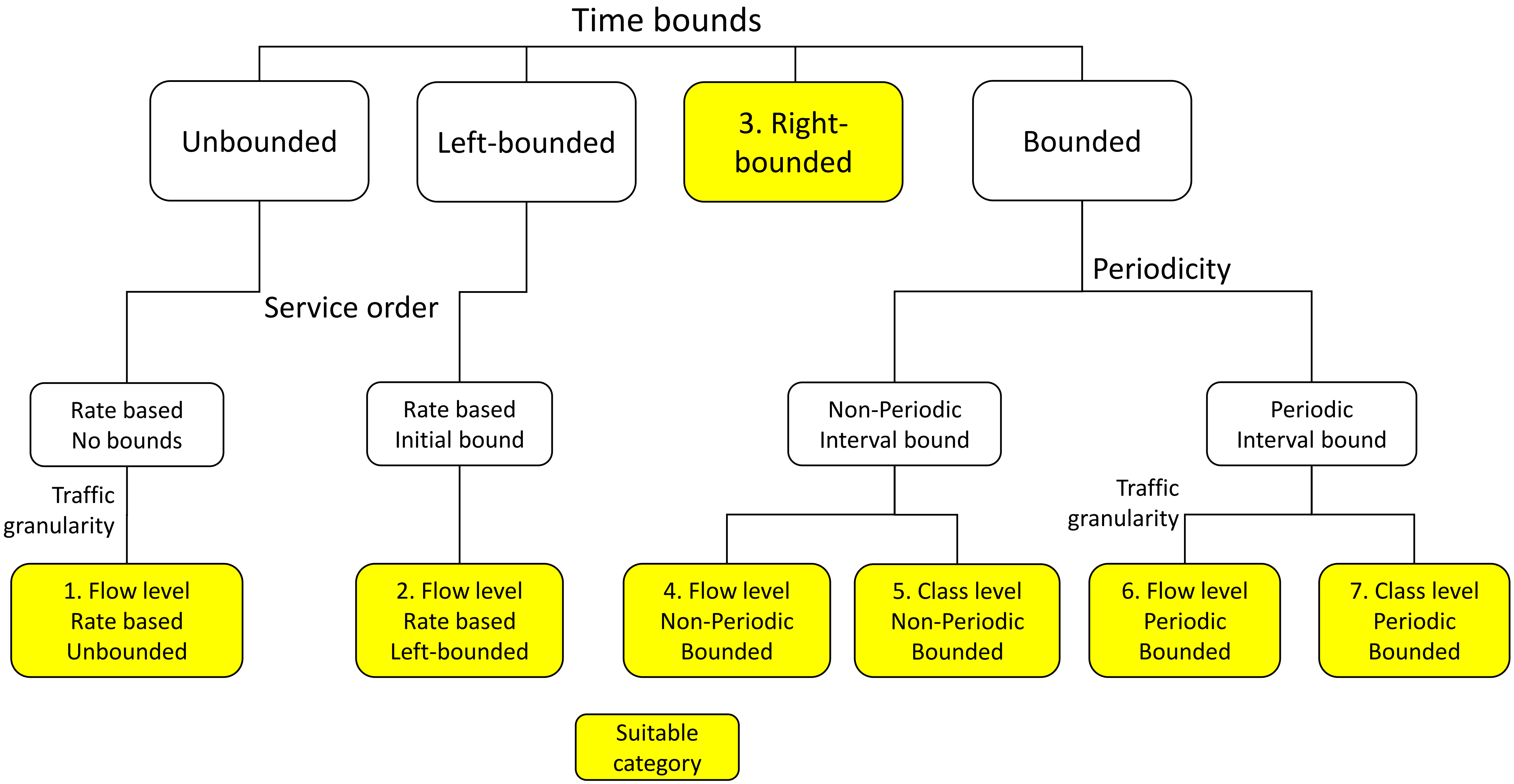
- For a solution with right bound, the bounds of packets decides the scheduling order.
- No other criteria is necessary.
- If a solution assures every packet can meet its bound at every node, it is suitable for DetNet.

Suitable category


Solutions without right time bounds cannot be described by Periodicity. They should be described by Service order.
Time bounds
Unbounded
Left-bounded
Right-bounded
Bounded
Bounded solutions are better described by Periodicity. The service order within a slot is not important. The bounded category is further divided because of the diversity of the solutions.
Service order
Periodicity
Service order
Rate based
Priority based
Arrival based
Non-Periodic
Periodic
Rate based
Priority based
Arrival based
Priority & Arrival-based solutions cannot meet tight latency bounds.
Suitable category
Unsuitable


Time bounds
Unbounded
Left-bounded
Right-bounded
Bounded
Service order
Periodicity
Rate based
Rate based
Non-Periodic
Periodic
Traffic granularity
Flow level
Class level
Flow level
Class level
Flow level
Class level
Traffic granularity
Flow level
Class level
Class level Rate based categories are not suitable, because of the burst intermix in core nodes.
Suitable category
Unsuitable
They are divided because of the great differences between flow and class level solutions.

Result: Seven categories are selected as suitable



Example data plane solution : ATS

Latency and Backlog Bounds in Time-Sensitive Networking with Credit Based Shapers and Asynchronous Traffic Shaping

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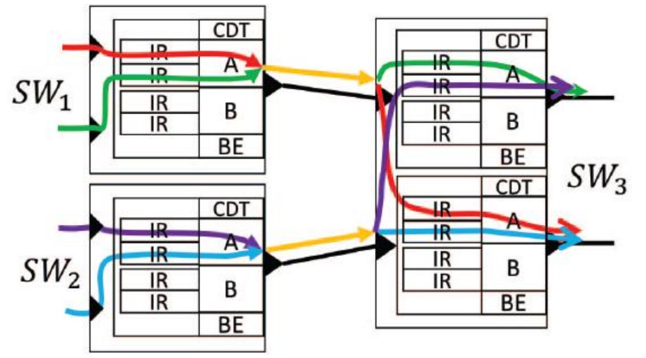

Fig. 2: Illustration of the queuing policy in interleaved regulators (IR) by TSN switches for four flows of class A.

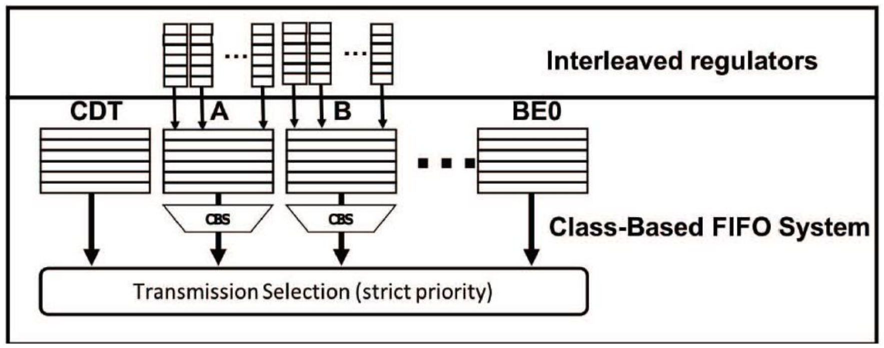

Fig. 1: Architecture of one TSN node output port.

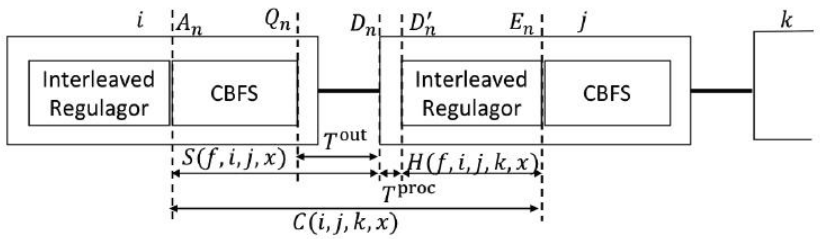

Fig. 3: Timing Model in TSN

$$C(i,j,k,x) = \sup_{f' \in F^x_{ijk}} S(f',i,j,x) + T^{\text{proc,max}}_{ij}. \quad (6)$$

Theorem III.2. *A tight upper bound on the response time in the CBFS of node i (following the interleaved regulator) for flow f of class $x \in \{A, B\}$, going from node i to j, is:*

$$S(f,i,j,x) = T^x_{ij} + \frac{b^{\text{tot},x}_{ij} - \psi_f}{R^x_{ij}} + \frac{\psi_f}{c_{ij}} + T^{\text{var,max}}_{ij}, \quad (5)$$

where the parameter ψ_f depends on the flow f and the type of regulator, namely, for LRQ: $\psi_f = L_f$ and for LB: $\psi_f = M_f$.

T^x: the delay due to the upper class traffic. For A class, the dominant factor for T^A is = {total CDT burst / (Link capacity-total CDT rate)}

R^x: the allocated rate to the class

The dominant factor is {sum of max bursts of / the allocated rate to} the class.

The IR does not increase the worst latency of the class-based FIFO system (CBFS).

$$b^{\text{tot},x}_{ij} = \sum_{f \in F^x_{ij}} b_f$$

for LRQ: $\psi_f = L_f$ and for LB: $\psi_f = M_f$

M: minimum packet length
c: link capacity

f: flow
x: class
i, j, k: nodes
n: packet

Example data plane solution : ATS

Latency and Backlog Bounds in Time-Sensitive Networking with Credit Based Shapers and Asynchronous Traffic Shaping

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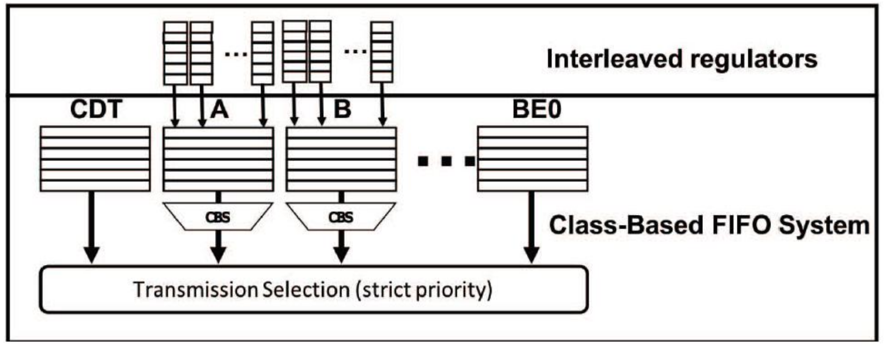

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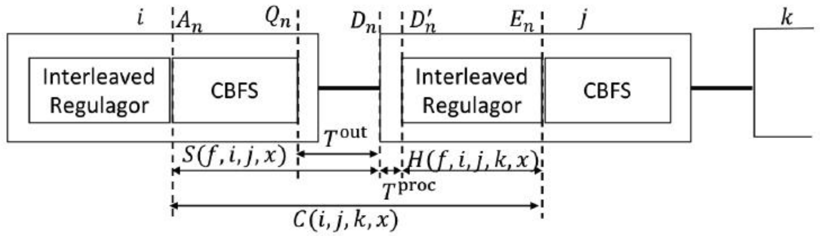

Fig. 3: Timing Model in TSN

The IR does not increase the worst latency of the class-based FIFO system (CBFS).

The dominant factor is {sum of max bursts of / the allocated rate to} the class.

Example data plane solution : ATS

- IR is FIFO but HoQ's eligible time is determined based on the flow's state and service rate.
- The eligible time is the governing factor for the packet release time to the CBFS. → ATS is left-bounded.
- However, the CBFS decides the schedule of the service.
- ATS is class-level, priority-based

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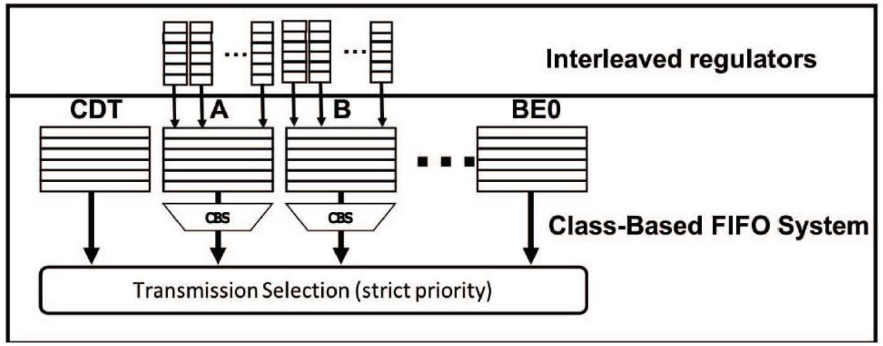

Fig. 1: Architecture of one TSN node output port.

> There are cases in which a single solution consists of multiple functional entities that treat packets according to multiple traffic entities of different granularities. In such cases, it is defined that the functional entity with the coarsest granularity is dominant, thus the whole solution belongs to the coarsest granularity category.

Taxonomy of ATS

Criterion		Categories (Level 1)			
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Thank you

- Please take a look at

  https://datatracker.ietf.org/doc/draft-joung-detnet-taxonomy-dataplane/

- Please share your comments and questions.
- References:

[1] J. Migge, J. Villanueva, N. Navet, and M. Boyer. (Jan. 2018). Insights on the performance and configuration of AVB and TSN in automotive Ethernet networks. Embedded Real-Time Software and Systems (ERTS 2018), Toulouse, France. [Online]. Available: https://hal.archives-ouvertes.fr/hal-01746132

[2] N. Navet, J. Villanueva, J. Migge, and M. Boyer, “Experimental assessment of QoS protocols for in-car Ethernet networks,” in 2017 IEEE Standards Association (IEEE-SA) Ethernet & IP @ Automotive Technology Day, San-Jose, Ca, Oct. 2017.

[3] Joung, J. and J. Kwon, "Zero jitter for deterministic networks without time-synchronization", IEEE Access, vol. 9, pp. 49398-49 414, doi:10.1109/ACCESS.2021.3068515, 2021.