Analogies across Hubs and Routers in the Physical and Digital Internet

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Logistics, some numbers

Imports & Exports
$16 Trillion

Imports & Exports
~60% worlds GDP

Maritime Transport
> 10.6 million tons

272 million containers delivered

Still, very innefficient!!!

67 million empty containers delivered

23% of miles traveled empty

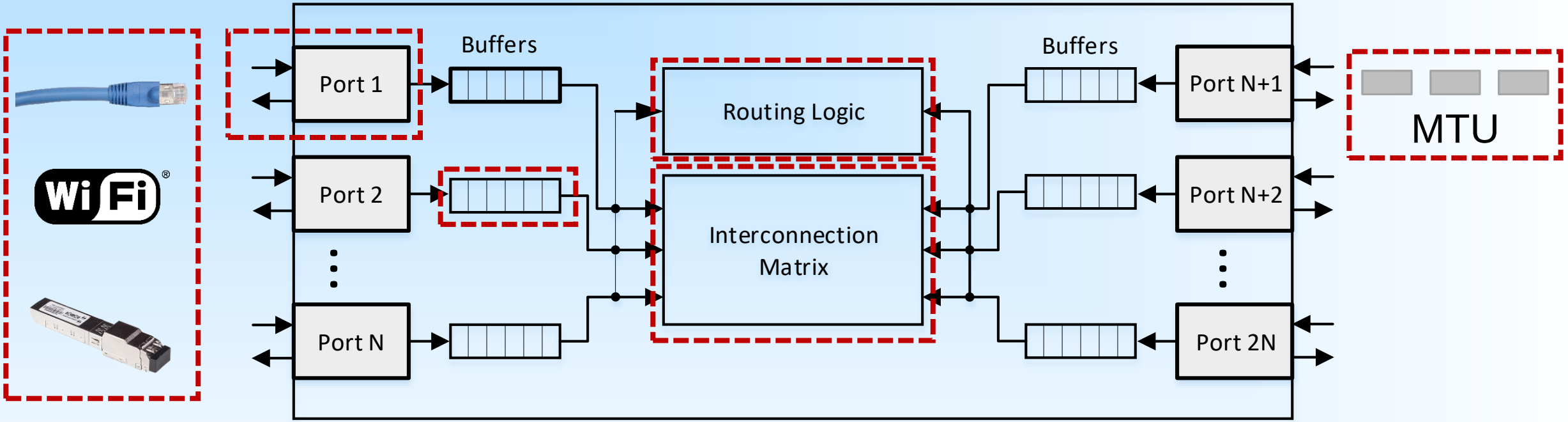
Average container load of 30-40% in laden trips

Problems and approaches

- Problems
  - Need for sharing data, events, information, of collaboration across agents
  - Need for synchromodality
  - Need for routing algorithms for logistics
  - Need for common semantics
- Approach
  - Start by defining a common, general model of operations in hubs
    - Inspired on digital internet
  - Leverage models as common semantics for creating new algorithms

Digital Internet: Routers

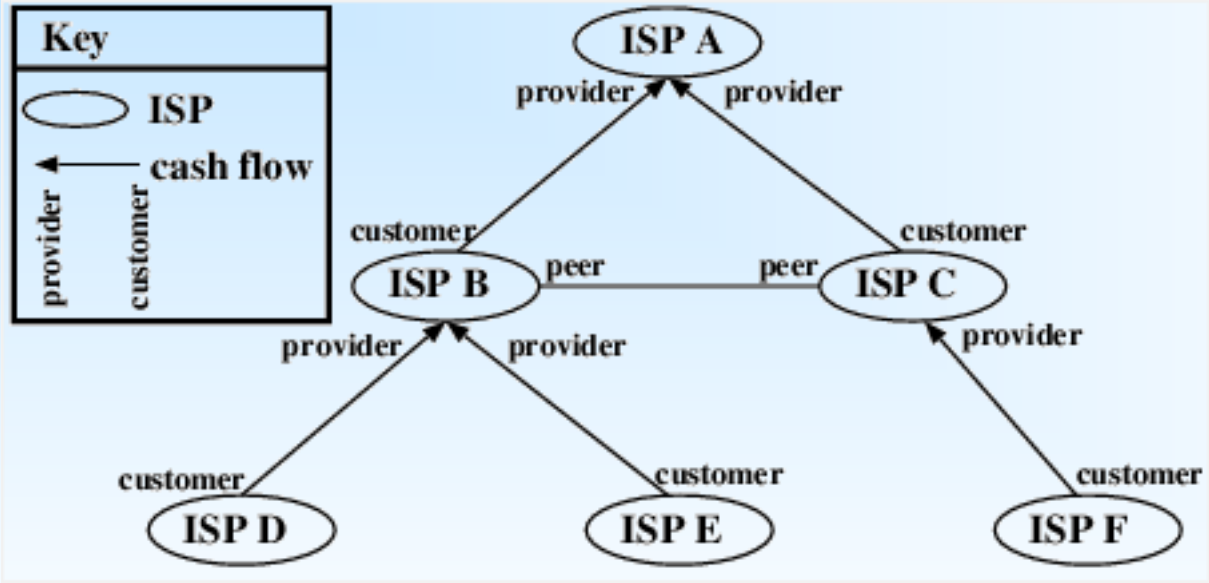
Main features of a router



Digital Internet: Routers

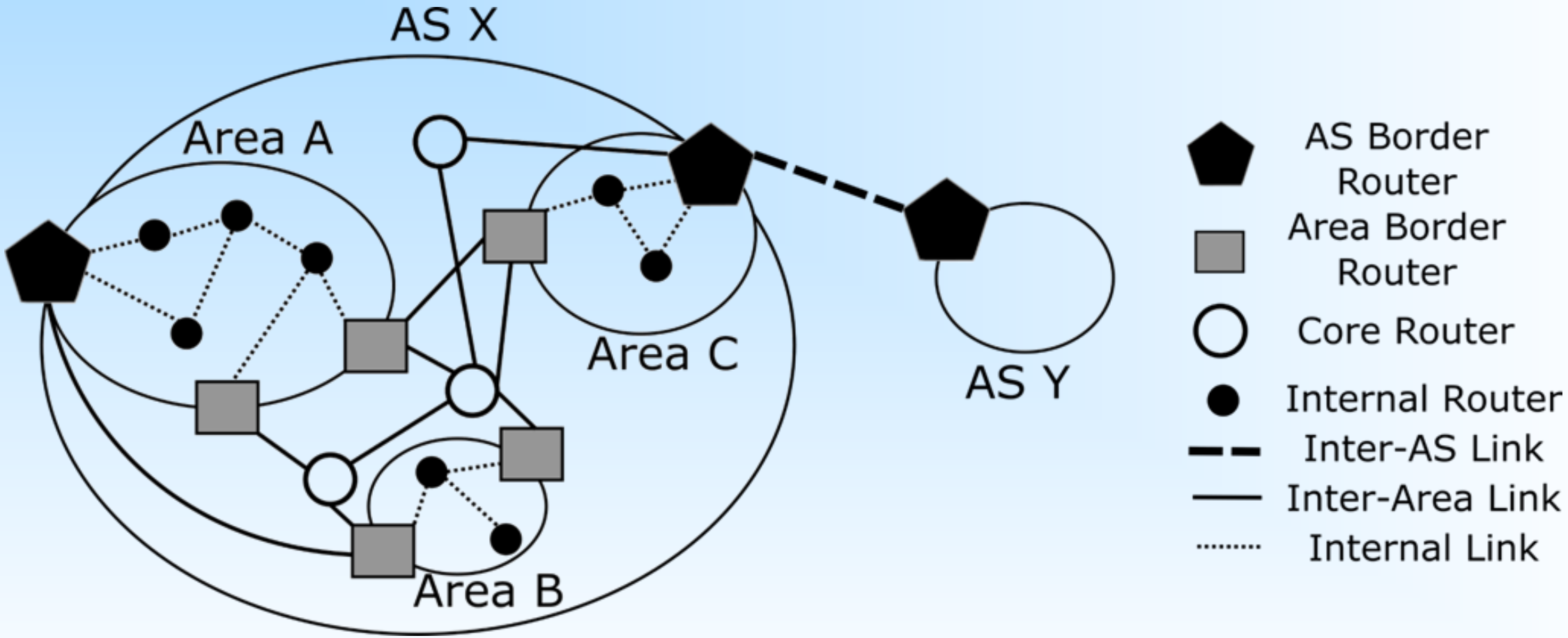
Internet Structure and types of router

- Digital internet structured as a hierarchical tree of Autonomous Systems (AS)
- AS: “connected group of one or more IP prefixes run by one or more network operators which has a single and clearly defined routing policy”.
- Different relations among ASs:
  - Peering
  - Customer
  - Provider,…



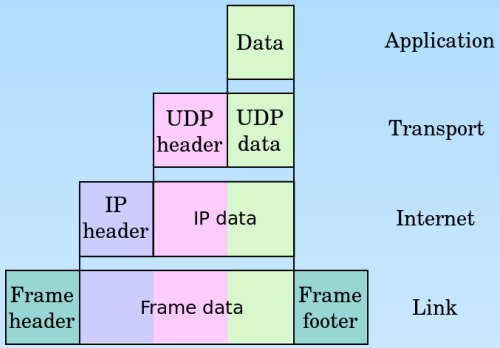
Digital Internet: Routers

Internet Structure and types of router

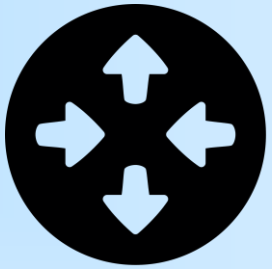


Digital Internet: Routers

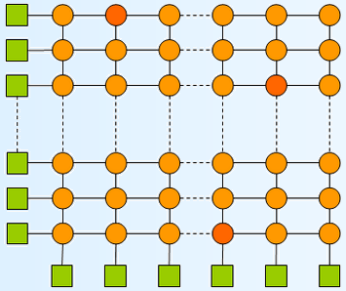
Operations



De-encapsulation
Encapsulation



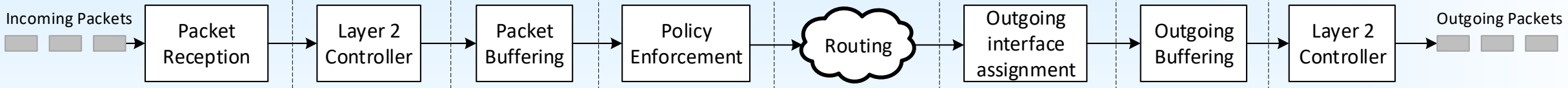
Routing



Forwarding

a) Non-AS Border Router

b) AS Border Router



Reception of Packet through Physical mean

Integrity check, deencapsulation

Awaits for processing slot

Policy check

Mapping of the packet to the outgoing interface

Waits for the link to be available

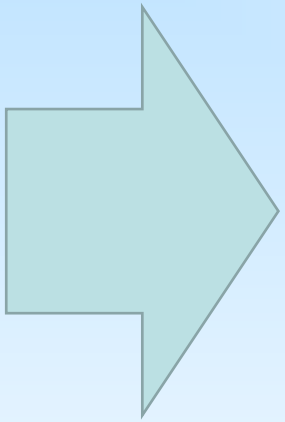
Encapsulation

Physical Internet: Hubs

Main features of a hub

Physical Internet

- Transport Modes
- Inbound/Outbound docks
- Turnaound time
- Storage areas
- Package reallocation
- Decomposition/composition



Digital Internet

- Physical modes
- Ports
- Computational latency
- Buffers
- Package reallocation
- De-encapsulation/encapsulation

Physical Internet: Hubs

Types of hub

- Multiple taxonomies in the literature
  - Single dimension (size OR facilities OR services OR functional hierarchy)
  - Multiple dimensions (Higgins et *al.*): area of influence, scope of activities and variety of services
- Our proposal
  - Multiple dimensions: area of influence, variety of services, largest and smallest handling units, intermodality capabilities, warehousing capabilities
- Resulting categories:
  - Gateways
  - Large regional distribution hubs
  - Classification centers

Physical Internet: Hubs

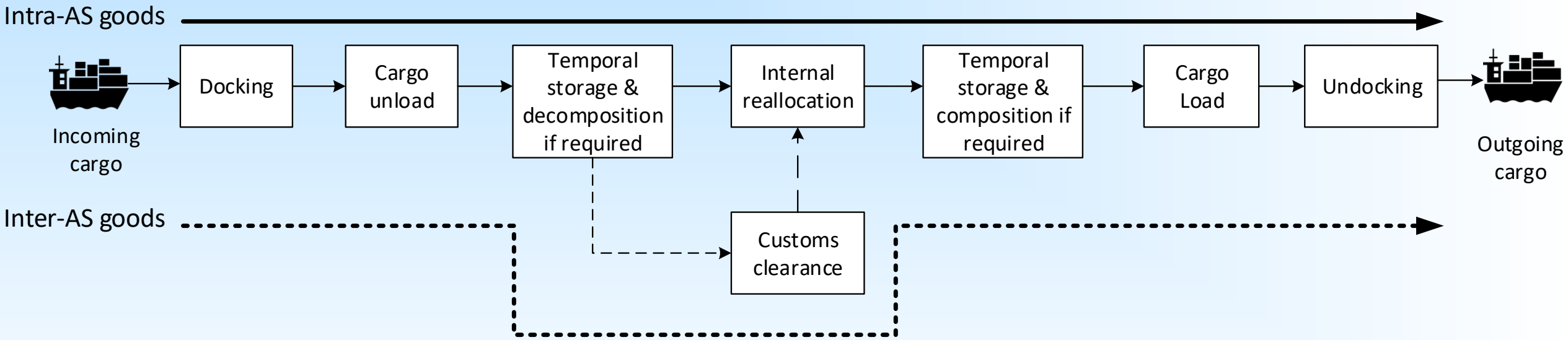
Autonomous systems in the Physical Internet

- Autonomous Systems in the Physical Internet:
  - We identify ASs with single markets (SM), economic unions (EU) or countries for four reasons: no internal trade barriers, a common external tariff, and free factor and asset mobility.
  - These areas are governed by a clearly defined and common set of rules for all logistics agents operating within. Similarly, any goods coming from outside the AS have to go through a customs clearance, subject to tariffs, economical policies and agreements.
  - ASBRs: Gateways
- Within the AS
  - Areas and sub-Areas: regions with dense trade networks can be modeled as areas or sub-areas. ARs and CRs represented by large regional distribution hubs.
  - Local networks: metropolitan areas and last mile. Internal routers equivalent to classification centers.

Physical Internet: Hubs

Operations

- Proposed model for operations in any type of hub



Physical Internet: Hubs

Operations: using the model

- It's the semantics!
  - Having a common model helps defining metrics and algorithms regardless of the type of hub.

The following metrics, Tav and Ts, could be common for any hub:

$$T_{av} = ETA + T_{dk} + \sum_{i=1}^{k} T_u^i + T_{dc},$$

$$T_s = T_{dk} + \sum_{i=1}^{n} T_l^i + \sum_{j=1}^{m} T_u^j + T_{udk},$$

However, their inner parameters depend on the type of hub

Physical Internet: Hubs

Operations: practical cases

Proposed Model	Seaport	Intermodal distribution centre	Cross-docking classification centre
Docking (T_{dk})	Sea Traffic Management, Gate control Nautical services (pilotage, mooring, tugging)	Rail shunting operations Vehicle reception	Vehicle reception
Cargo unload (T_u)	Terminal Cranes (STS, RTG, RMG, SC, etc.)	Cranes (RMG, reach stacker, etc.)	Forklifts Human force
Storage & decomposition (T_{dc})	Bulk, general cargo, ITUs handling Open air - yard /warehouse storage	ITU handling, Decomposition in smaller handling units (PI-container) Open air - yard, Incoming dock -reception area, warehouse facilities	Incoming dock -reception area
Customs clearance	Customs inspection and clearance	N/A	N/A
Reallocation (T_r)	Cranes, Internal transport	Cranes, Internal transport, Conveying units, Forklifts	Forklifts, Conveying units
Storage & Composition (T_c)	Bulk, general cargo, ITUs handling Open air – yard /warehouse storage	ITU handling, Composition in bigger handling units (ITUs) Open air – yard, Outgoing dock – expedition area, warehouse facilities	Outgoing dock -expedition area
Cargo load (T_l)	Terminal Cranes (STS, RTG, RMG, SC, etc.)	Cranes (RMG, reach stacker, etc.)	Forklifts Human force
Undocking (T_{udk})	Sea Traffic Management, Gate control Nautical services (pilotage, mooring, tugging)	Rail shunting operations Vehicle reception	Vehicle reception

From Hubs to PI-Hubs

Discussion and Future Work

Digital Internet

- Pros
  - Negligible time in router. Routing depends on latency, bandwith,… or other metrics measured in the links.
  - Packets can be replicated without cost
  - Routing per-hop, adaptable
- Cons
  - Routing cannot be planned in advance
  - Difficulties with QoS

Physical Internet

- Pros
  - Control and physical plane are detached
  - Possible to model parameters related to operations
  - Perform forecasting and resource reservation
  - Enabler of synchromodality
- ToDos
  - Devise routing algorithms based on common semantics aimed at reducing costs, delivery time and emissions while providing flexibility and adaptability

Thanks for having us!

Any (easy) question?