IPIC PRESENTATION 2024

A PROTOCOL FOR NODE-TO-NODE TRANSSHIPMENT IN THE PI ANALOGIZING FROM INTERNET PRINCIPLES

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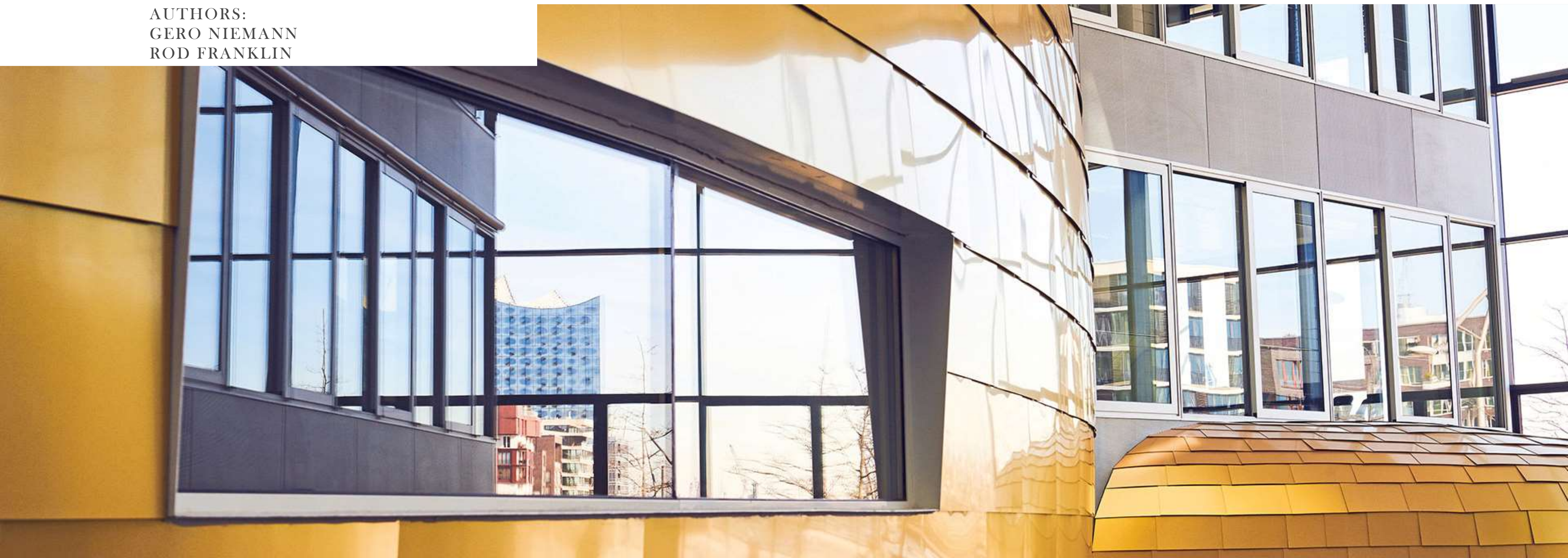


THE PI IS A FARMWORK FOR HORIZONTAL COLLABORATION THAT BUILDS ON INTERNET PRINCIPLES

Collaboration in supply chains is recognized as one of the most effective ways to improve freight transportation efficiency (Goldsby et al., 2014)

Horizontal collaboration
(Mason et al., 2007; Pan et al., 2019)

- Share information about their transport orders and delivery vehicles with central coordinator (Karam et al., 2021)
- Competition raises concerns about establishing a trustworthy partnership (Basso et al., 2019)
- Power of central coordinator creates competition law issues (Karam et al., 2021)

Vertical collaboration
(Barratt, 2004); Power, 2005; Stadtler, 2009)

Out of scope

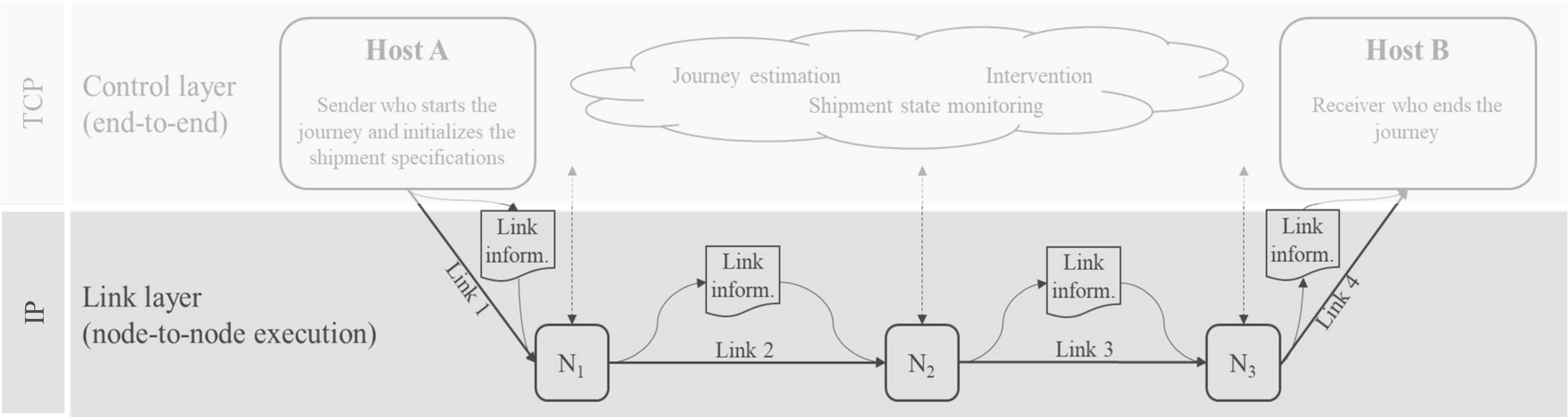
Physical Internet (Montreuil, 2011)
Internet principles
Distributed governance
No central coordinator needed

TCP/IP analogous protocols to operate the PI

WHAT WE ARE SEEKING FOR IN THIS PRESENTATION

- Most logistics operations are done by undefined rules
- Needed: Standards for collaboration – like TCP/IP on the Internet
- Proposed: First attempt for node-to-node transshipment facilitation
- Encouraged: Critique, feedback and ideas

TCP/IP AS THE BASIC FRAMEWORK FOR THE RELIABLE INTERCONNECTION OF NETWORKS



- Cost planning for the journey is performed by the control layer
- Cost planning is based on estimated route
- Decision on actual route is made on the link layer
- The focus of this paper is put on the link layer and the PI-link protocol
- The PI-link protocol facilitates shipment movement across a network of interconnected nodes

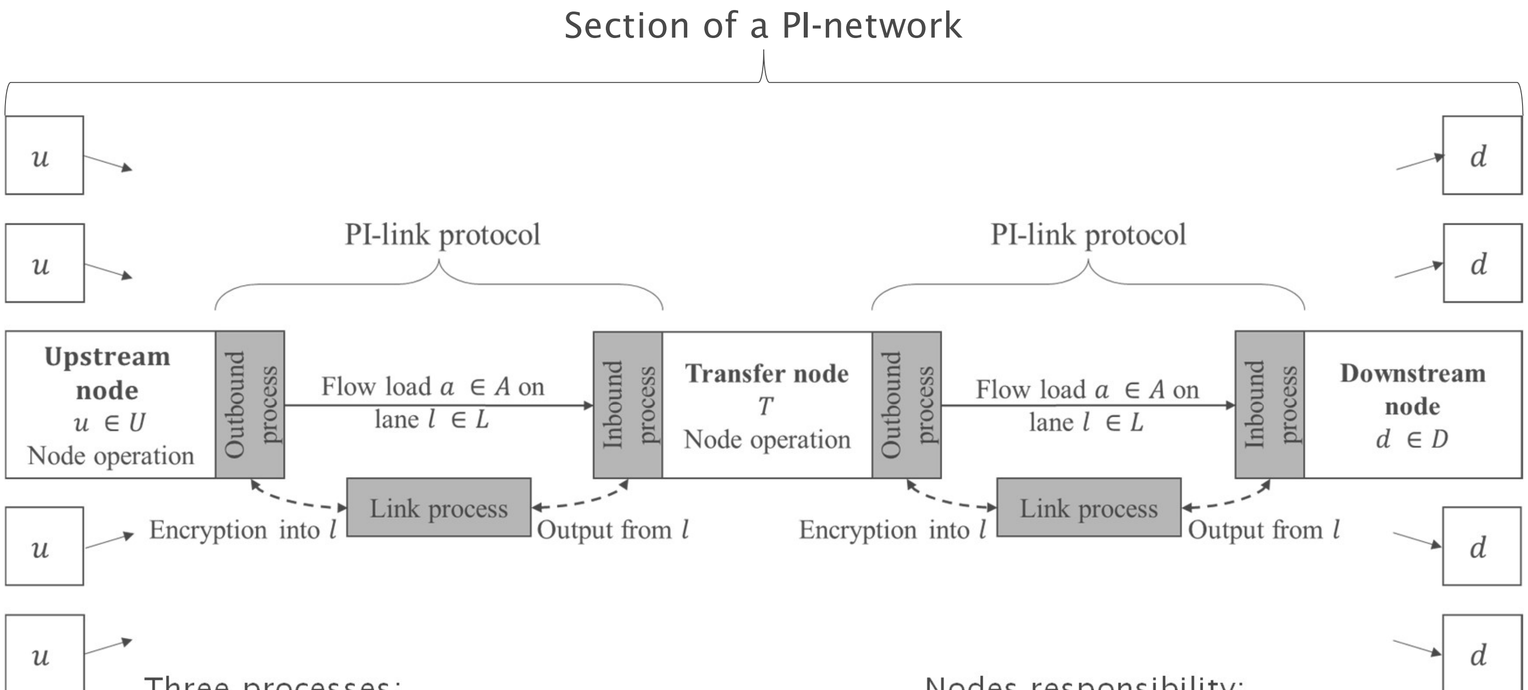
INFORMATION CARRIED BY THE PI-LINK PROTOCOL ARE CAPTURED BY A LINK LABEL

- Basic functions: (1) Shipment data sharing, (2) Shipment state monitoring (according to IP - Postel, 1981)
- The link header is dedicated to a transportation mean
- A transportation mean carries at least one but most likely several link components – shipments
- This contrasts to many other studies that only consider FTL (e.g. Briand et al., 2022; Achamrah et al., 2023)
- The PI-link protocol is general enough to work for any transportation mean

Link header (dynamic)			Prior node	Next node	Transportation mean	List of stops in transit to next node	
			Acc. money	Acc. time	Acc. emission		
	Link components (static)	Shipment 1	Shipment number	Fragmentation	Priority	Target money	Current money
			Origin	Fragment	Service requirement	Target time	Current time
			Destination	Dimension/Weight	Journey initiator	Target emission	Current emission
		Shipment 2					
		Shipment 3					

Adopted from the IP header (Postel, 1981)

THE PROCESSING OF THE LINK-LABEL INFORMATION CAN BE DESCRIBED IN THREE PROCESSES



Three processes:

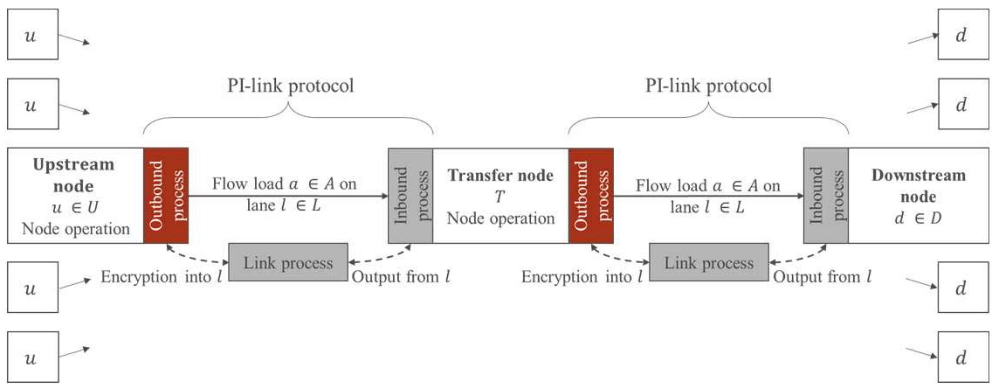
- Outbound process
- Link process
- Inbound process

Nodes responsibility:

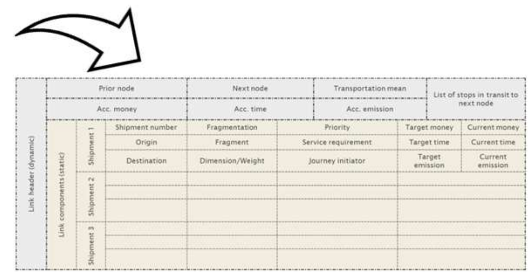
- Consolidation
- Routing
- Assignment

Not captured by PI-link protocol

OUTBOUND DISPATCH PROCESS

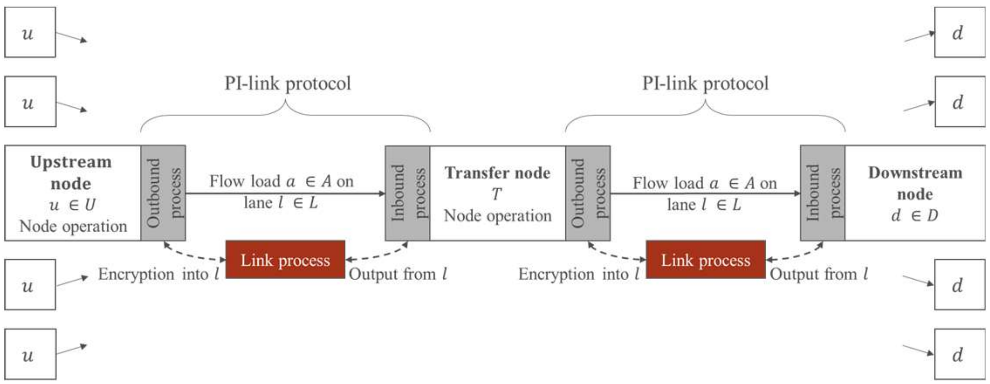


Process 1: Outbound dispatch	
Input: Receive $r_a \in R = 1$ including $spec_a$, $cc\_tar_a^l$ and $l \in L$ from $u \in U$	
for $r_a \in R = 1$ **do**	
encrypt $spec_a$ into l	// journey static shipment specification encryption
encrypt $cc\_tar_a^l$ into l	// link static cost target encryption
Output: Encrypted link l	// link established
end for	

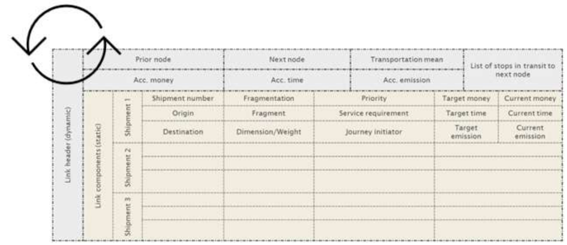


- Upstream nodes prepare loads (consolidation, routing, assignment)
- Shipment specifications and target costs are encrypted into the link
- Encryption prepares load journey -> carriers can plan accordingly

LINK TRANSPORTATION PROCESS



Process 2: Link monitoring	
Input: Encrypted link l	
for $a \in A$ on $l \in L$ **do**	
accumulate cc_a^l	// accumulation of cost along the link
end for	

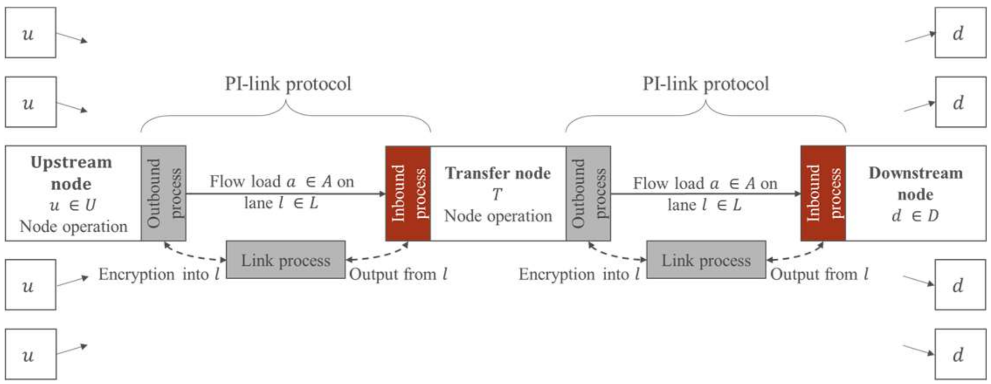


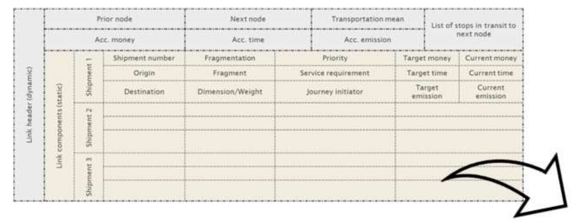
- Protocol tracks the load's progress (link monitoring)
- Accumulates all the costs occurring on the link

Unlike on the Internet, there are costs associated with movement:

- Money
- Time
- Emission

INBOUND RECEIPT PROCESS





Process 3: Inbound receipt

Input: Receive $a \in A$ from $l \in L$
for $a \in A$ on $l \in L$ **do**
 decrypt $spec_a$ from $l \in L$ // handover of load specification to node
 decrypt $cc\_tar_a^l$ from $l \in L$ // handover of target cost to node
 decrypt cc_a^l from $l \in L$ // handover of actual cumulative cost to node
 Input: Receive encrypted parameters $spec_a$, $cc\_tar_a^l$ and cc_a^l
 if $cc_a^{ul} > cc\_tar_a^l$ **then** // target-performance comparison
  retain a // retention of problematic load
  Output: Inform control layer on $cc\_tar_a^l$ exceedance
   Broadcast cc_a^l to control layer
 else
  Output: Broadcast cc_a^l to control layer
 end if
 purge cc_a^l
end for

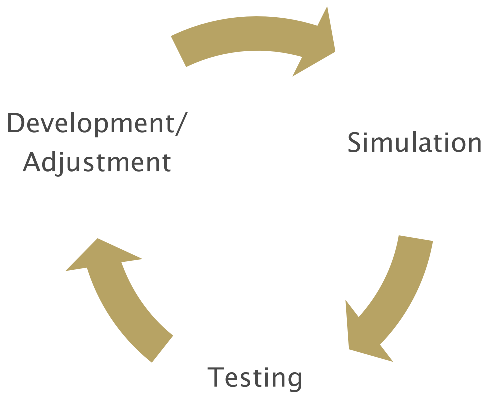
- Process starts as load arrives
- Decryption of information
- Updating of target costs
- Critical comparison between actual and target costs
- In case of discrepancy, the requests further instructions from control layer (shipment initiator)
- Link will be purged

KEY TAKEAWAYS ON THE PI-LINK PROTOCOL

- Shipment data sharing
- Shipment state monitoring
- Cost evaluation at end of the link
- Adherence to contracted shipping specifications

NEXT STEPS: TESTING OF THE PROTOCOL

- What we **don't** assess: How the protocol improves an existing system
- What we want to test: If the protocol capture, convey and adapt to certain information
- Close relation to the development process of the protocol



Has the protocol all prerequisites to manage unplanned disruptions on the link?

Experiment 1

Cause: Consolidated shipment is assigned to a specific link

Effect 1: Protocol specified information are encrypted into the link

- Outbound dispatch

Effect 2: Costs accumulate along the link

- Link monitoring

Effect 3: Shipment arrives at node

- Inbound receipt

Experiment 2

Cause: Shipment can not get to the node as planned caused by subsequent node disruption or lane blockage

Effect 1: Recall

- "Next node" field changes to the prior node
- "List of in transit stops" changes
- Reiteration of the link setup process at prior node

Effect 2: Rerouting

- "Next node" field changes to the alternative node
- "List of in transit stops" changes

Experiment 3

Cause: Transportation mean brakes down while on the link

Effect: …

Experiment X

Cause: …

Effect: …

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THANK YOU FOR YOUR ATTENTION!

QUESTIONS?

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