IPIC 2016

Workshop TA2: Open Logistics Interconnection Model & Protocols

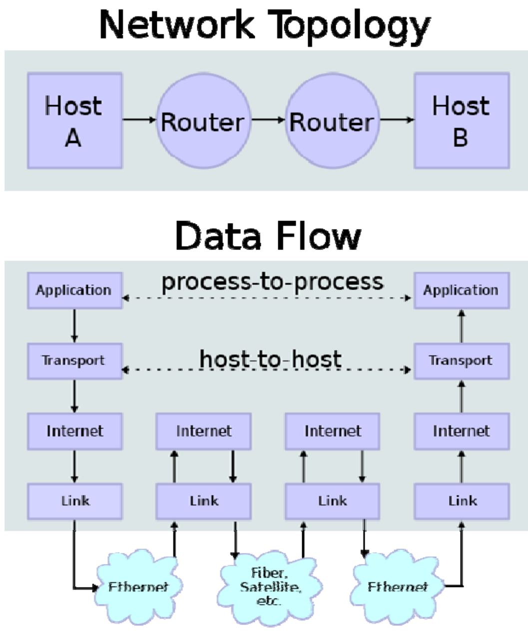
Towards a smart hyperconnected era of efficient and sustainable logistics, supply chains and transportation

IPIC 2016 - 3rd International Physical Internet Conference

June 29-July 1, 2016 | Atlanta, GA USA

Open Logistics Interconnection Model & Protocols

In telecommunications, interconnection is the physical linking of a carrier's network with equipment or facilities not belonging to that network. The term may refer to a connection between a carrier's facilities and the equipment belonging to its customer, or to a connection between two (or more) carriers.



Sources: wikipedia

Open Logistics Interconnection Model & Protocols – OLI model

Ballot, E., B. Montreuil, and M. Thémans, *OPENFRET: contribution à la conceptualisation et à la réalisation d'un hub rail-route de l'Internet Physique*, PREDIT, Editor. 2010, MEDDAT: Paris. p. 114.

Montreuil, B., E. Ballot, and F. Fontane. *An Open Logistics Interconnection Model for the Physical Internet*. in *INCOM 12 Conference*. 2012. Bucharest, Romania: IFAC.

Data transmitted to the lower layer

Data transmitted to the upper layer

Open Logistics Interconnection Model & Protocols

Agenda:

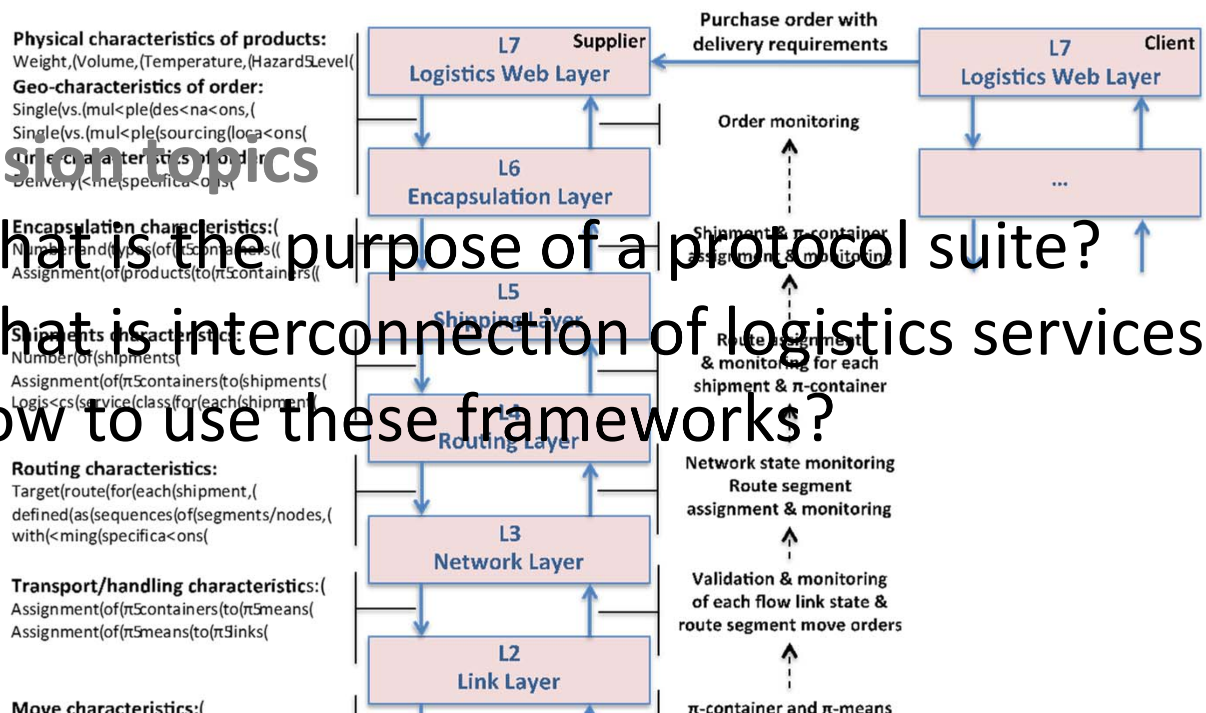
- **Presentations**

  Evaluating five typologies on costs and requirements for hyperconnected logistics networks
  Wout Hofman

  Networking in the Real World: Unified Modeling of Information and Commodity Distribution Networks
  Amitangshu Pal and Krishna Kant

- **Discussion**

Open Logistics Interconnection Model & Protocols



Discussion topics

- What is the purpose of a protocol suite?
- What is interconnection of logistics services?
- How to use these frameworks?
- …

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NETWORKING IN THE REAL WORLD: UNIFIED MODELING OF INFORMATION AND PERISHABLE COMMODITY DISTRIBUTION NETWORKS

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The Perishability Challenge

- Perishable Information Distribution
  - Increasing amounts of time sensitive information, including streaming & other real-time data.
  - Not well served by traditional “best effort” Internet.
  - New architectures to handle these (e.g., content centric networks)
- Perishable Commodity Distribution
  - Perishability ⇔ Efficiency tradeoff
  - Varying perishability of products ➔ Mixing products very difficult
  - Local food movement leads to unique local logistics challenges.
  - Integration between local & nonlocal logistics a must
- Goal:
  - Study synergies between Perishable commodity vs. Information distribution to advance both fields

Information vs. Commodity Distribution

- Many similarities
  - Movement of packages or packets between “nodes” with various capabilities
    - Change of mode (or “media”), e.g., truck to railcar or barge
    - Store and forward w/ potential product remix.
  - Accentuated by emerging standardization (e.g., GS1) & capacity sharing (e.g., 3PL) ideas
  - Multiple flows with varied SLA requirements
  - Privacy and security requirements (e.g., privacy preserving distribution)
  - Dynamically changing availability and demand

Information vs. Commodity Distribution

- But many key differences as well
  - Recursive bundling (boxes within boxes)
  - Physical goods cannot be "cloned" (except at source)
  - Packet "carrier" (e.g., truck) and auxiliary resources (e.g., driver, loading equipment)
  - Complex requirements (e.g., long term contracts).

- Can we create a unified model that comprehends
  - Information Networks (IN)
  - Perishability Commodity Distribution Networks (PCDN)

A Unified View

- 5 layer model similar to TCP/IP protocol stack
- Two types of packets
  - Non-clonable → Transportation of perishable goods
  - Clonable →Computer Networks
- Packets can be of different QoS classes
  - Based on perishability or other handling characteristics
  - Each class has a perishability function within 0 and 1

Virtualization Layer
Transport/Delivery
Routing & Distribution
Media Switching Layer
Physical Layer

Physical layer → Layer 1

- Deals with actual movement of packets along a media segment/channel
  - IN: Transports "frames" over a wired/wireless channel
    - Max frame size, smaller sizes less efficient
  - PCDN: Physical transport over a media segment (road, rail, waterway, or air)
    - Transport in units (e.g., PI containers) that fit the carrier (e.g., truck)
    - Carrying smaller PI containers less efficient
- PCDN Channel is far more complex
  - Multiple roadway segments from point A to B with different capacities.
  - Alternate routes even at layer 1 – HWY vs. normal road
  - PCDN traffic of interest just a small part of all traffic that's flowing
    - Much higher uncertainties & little controllability
- Why is abstraction useful?
  - Statistical description of the path (e.g., net capacity)
  - Can be compared to wireless link w/ fading & interference

Media Switching layer → Layer 2

- Media access control
  - Assigns the "channel" (e.g., path to next transfer point)
    - Transfer point: A switch in IN, and a physical transfer point for PCDN
  - May do reframing
    - IN: Break up into smaller frames, make use of jumbo frames
    - PCDN: Truck full of PI containers → Rail car full of PI containers
    - Damaged (rotten) frames → Discard & request replacement
- Complexities in PCDN
  - PCDN needs to assign carriers (e.g., trucks, rail cars) to the packets
  - PCDN needs additional resources (e.g., drivers)
  - PCDN invariably needs to return damaged goods
    - Reverse logistics added complication
- Layer 2 routing
  - IN: Transport between successive routers (layer 3 endpoints)
    - Intermediate transfer point (switches & protocol bridges) with change in media (wired, wireless, optical, …)
  - PCDN: Transfer of PI containers from a distribution center to next
    - Intermediate transfer points may involve media changes (e.g., truck to railcar)

Routing & Distribution layer : Layer 3

- End-to-end transfer of packets/packages
  - IN: Transfer from src to dest via multiple routers
    - May fragment a TCP stream into multiple IP datagrams
    - Different types of packets may be mixed before framing
  - PCDN: Transfer from src to dest via multiple distribution centers
    - May fragment stream of goods into PI containers
    - Bundling of different types of contents together quite common
- Complexities in PCDN
  - May involve recursive bundling (boxes within boxes)
  - Involves allocation & tracking L3 resource like containers
  - Buffer space management lot more complex (contracts?)
- Routing needs unique IDs
  - For IN, this may be a message or datagram sequence number
  - For PCDN it may be the GTIN, GSIN, SSCC number
- Why is the abstraction useful?
  - Numerous routing algorithms explored in IN
  - Emerging notions of content centric networking

Transport/Delivery Layer : Layer 4

- End to end (src to dest) delivery of packets
  - IN: User endpoint to user endpoint
  - PCDN: Farm to retailer/business (do not consider retail purchases)
- Similarities
  - Flow control, packetization, resource allocation, retransmission of damaged goods.
- PCDN complexities
  - Batching (accumulating enough goods for transport) an essential component
    - Needs to deal with tradeoffs between perishability, cost, efficiency
  - Contract based delivery scheduling (less flexible flow control)
  - Quality degradation with time & product mixing much more challenging
    - Lateral distribution to handle perishability
  - Reverse logistics for returns and replacements
- Why is the abstraction useful?
  - Content centric & just-in-time media delivery

Virtualization Layer : Layer 5

- Virtualization goals in IN & PCDN
  - Share network capacity efficiently among different applications
  - Provide stable capacity allocation and isolation
- Examples for PCDN
  - Define a "HP Transport" as a VS for transporting highly perishable (HP) between a src & dest
    - Similar VSs for moderate and low perishable items
  - Separate VSs for different types of customers → VS for premium customers or other low-end customers
- Key Challenges
  - The mapping of virtual resources on physical resources
  - Lack of visibility into the entire network and the difficulty of tracking the entire network state
- Why is the abstraction useful?
  - Increasing complexity of both cloud computing and logistics

Resource Management in UNM

- The unified network involves acquisition of certain resources at each layer of the network
  - Need to obtain carriers & containers to carry products
  - Return of carriers & containers (full or empty)
  - Availability & proper distribution of carriers and containers impacts timeliness & freshness of perishable product delivered.
- Resource management crucial for modeling performance.
  - Details of representation and usage in the paper
- A simple modeling illustration

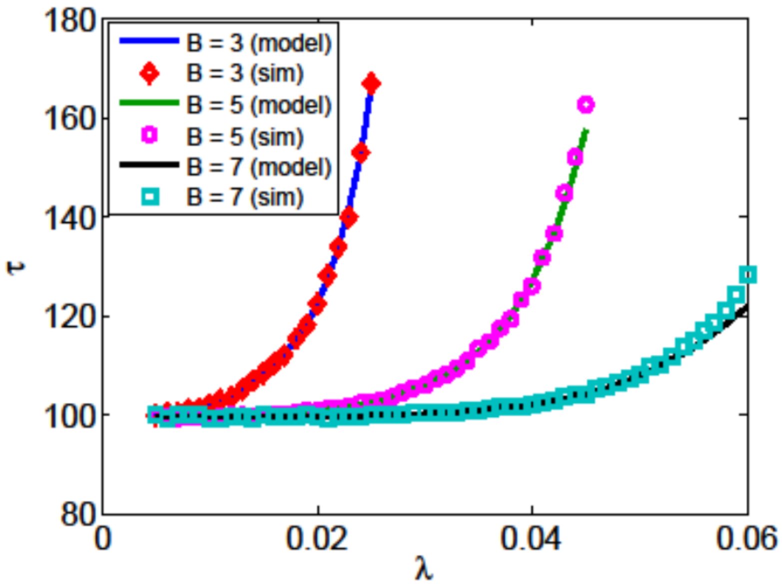
Analytical Model for Commodity Distribution in UNM

- Assumed a bulk queuing theoretic model:
  - Trucks are serving the distribution centers (DCs) that are placed uniformly → truck service time is deterministic
  - Packets are arriving at the distribution center as a Poisson process
  - Distribution centers have finite buffers ($\mathcal{M}$ packages)
  - Packets are wasted when the DC buffer is full
  - DC queue is served upon arrival of a truck
  - The truck loads almost B packages at a DC
    - If <= B packages → entire queue is loaded onto the truck → truck leaves without waiting for other packages
  - The truck capacity is assumed to be $N.B$ → each DC reserves a space of B units in the truck
  - This queuing discipline falls under the category of $M/D^B/1/\mathcal{M}$ queue

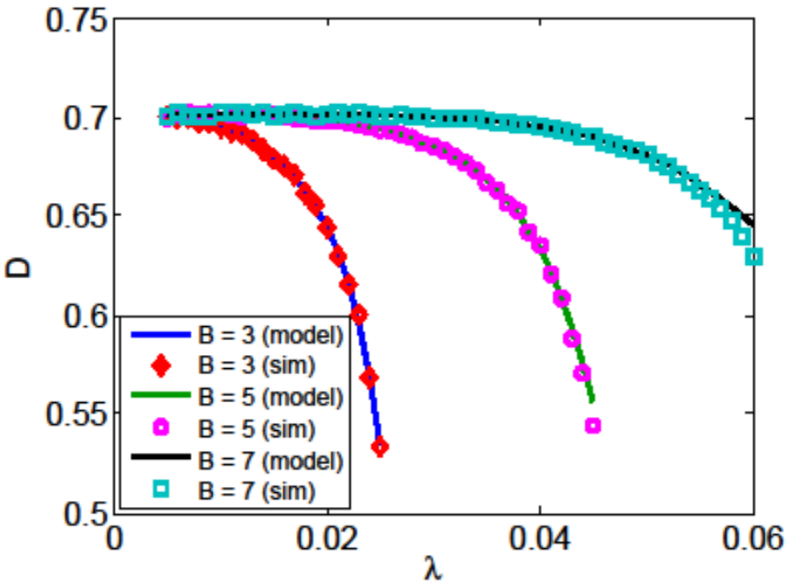
Analytical Model for Commodity Distribution in UNM

- 100 nodes are placed in an area of 100x100 sq. m.
- Package freshness degrades linearly with time at a rate of 0.25% (at delivery centers) and 0.35% (on truck)
- Package delay increase → delivery quality decrease
  - With lesser batch size *B* → higher truck access time
  - With higher package arrival rate at DC → higher waiting time

Package delay against packet arrival rate

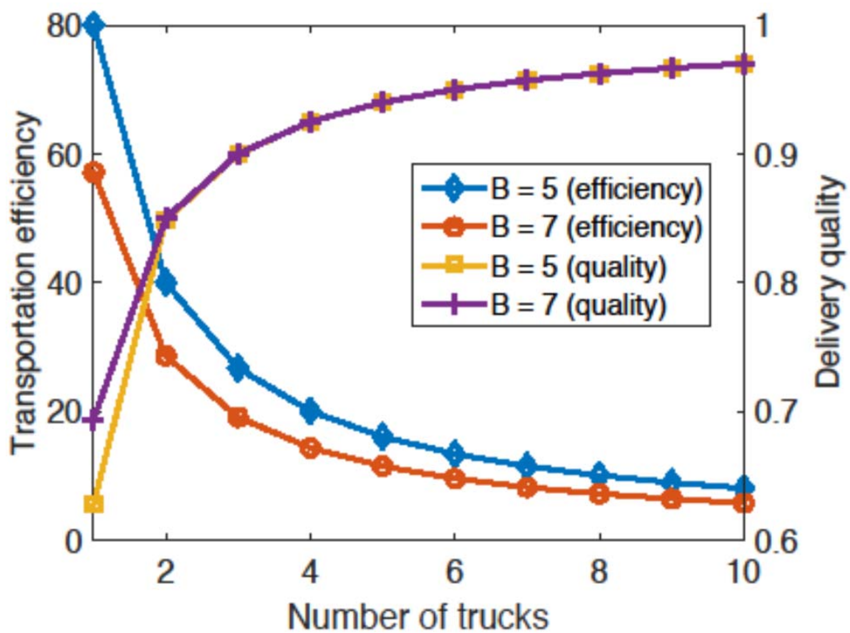


Package delivery quality against packet arrival rate



Analytical Model for Commodity Distribution in UNM

- Tradeoff between transportation efficiency and delivery quality:
  - Increase in number of trucks → improves the delivery quality as waiting time of the packages reduces
  - However the transportation efficiency reduces due to lesser available packages at each DC
  - Increasing B loads more number of packages at any particular DC → improves the delivery quality especially in case of smaller number of trucks



Conclusions

- We considered the synergies between information and commodity distribution disciplines
  - Devised a unified model to capture both
  - Discussed an analytical framework to get an insight regarding the key performance parameters
  - There is always a tradeoff between the transportation efficiency and delivery quality
- Ongoing works:
  - We designed a data center optical network inspired by integration of local & nonlocal logistics
  - Use the perishable logistics concepts in content centric networks
  - Making the perishable logistics more resilient to spoilage and contamination by sensing and local delivery