Applying concepts of telecom networks to logistic networks – towards new business roles and - models for the Physical Internet

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Abstract: *Over the last couple of years, virtualization of telecom networks by separating software from hardware led to new business models. Since the Physical Internet is considered as the logistics equivalent of the Internet, it might be worthwhile to assess developments of the telecom sector and investigate its potential to supply and logistics. Future directions for innovative business models, - roles, and required functionality are explored and discussed. Data sharing is a prerequisite to realize these models with its supporting functionality.*

Keywords: *virtualization, Software Defined Networks, business innovation, Physical Internet*

1 Introduction

The Physical Internet (Montreuil, Meller, & Ballot, 2013) is about the creation of various layers in which modularized packages move from origin to destination (Ballot, Liesa, & Franklin, 2018). Routing protocols, data sharing, and pricing and procurement models are amongst others identified as research topics. These routing protocols can be implemented anywhere, e.g. in a node, a Logistics Service Provider, or even an intelligent asset.

These types of research questions have already been addressed in the telecom sector, where there is a need for standardization to increase market share and usability of smart devices. Various protocols for system-to-system have been developed and implemented, including the support of mobile and satellite communication. This sector evolves into virtualization of telecom networks meaning that communication networks are collection of physical links (cable, fiber, microwave links, ...), switches, and a number of processing functions implemented by software. SDN (Software Defined Network) and NFV (Network Function Virtualization) are game changers from a business perspective, implying for instance rapid deployment of communication networks on a shared infrastructure. Logistics can be constructed in a similar manner, consisting of assets that are service providers to construct their logistics network. These assets can be anything, ranging from warehouse, terminals, and cross-docking centers to trucks, vessels, and barges.

This paper analyses development of business in the context of the Physical Internet by comparison with the telecom sector. First of all, developments in the telecom sector are discussed, secondly, their analogy to logistics is presented and thirdly differences are assessed.

2 Telecom developments

Virtualization of telecom networks reflects the understanding that communication networks are a collection of physical links (cable, fiber, microwave links, ...), switches, and a number of processing functions implemented by software. SDN (Software Defined Network[1]) and NFV (Network Function Virtualization[2]) are main developments and game changers from a business perspective. SDN has introduced functional separation of software and hardware and routing and switching functions of routers. NFV has introduced the idea that Network Functions, required to operate a communication network, can be implemented by software, that can run at any connected location offering sufficient processing, storage, and connectivity. Hardware like routers have their firmware, offering Application Programming Interfaces (APIs), that can be programmed by Network Functions like routing.

Using SDN/NFV as leading ideas, bodies like 3GPP (Third Generation Partnership Project[3]) are developing 5G, which will allow enormous flexibility to operators in operating their networks on a shared infrastructure and particular cloud providers offering computational and storage capabilities. Since the majority of network functions, if not all, is implemented by software, running on general purpose hardware (cloud / data center), an network service provider can easily create new instances of network functions in case of increased user demand or to cater with DOS (Denial Of Service) attacks. It includes having sufficient cloud resources, setting up virtual machine(s) and relevant network function software, and connecting these network function to corresponding network functions already in operation. The same holds for a situation where one network function might fail – new instance can be created and deployed rapidly.

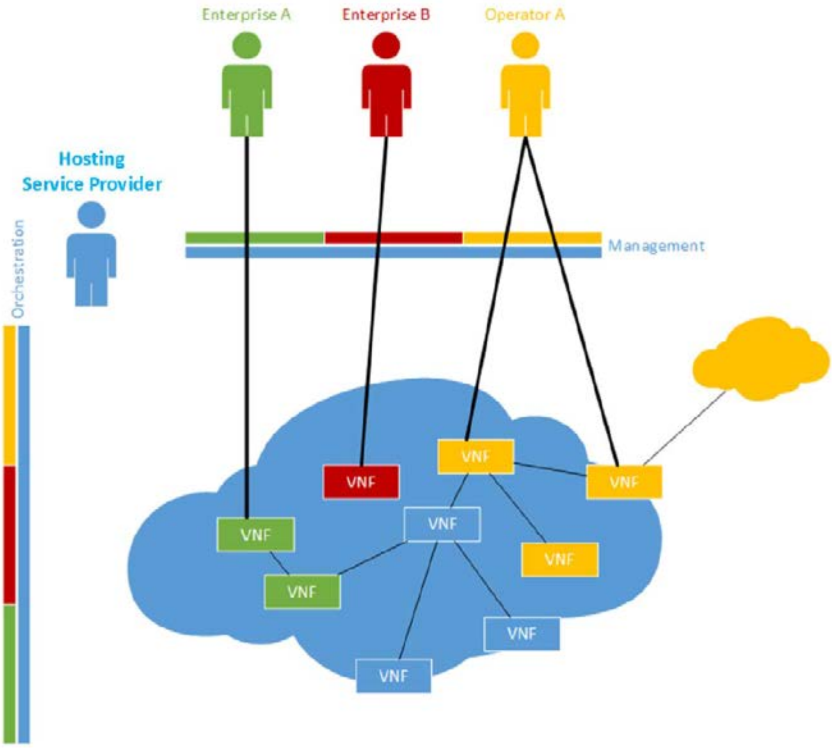

Figure 1: Multi-tenant network (source: ETSI[4])

By including automated tools for monitoring a network and matching the required network capacity with the demand for connectivity and data exchange to users, it is possible to construct a fully automated system that will manage such a network.

[1] Example of OpenFlow can be found at https://www.opennetworking.org/
[2] https://www.etsi.org/technologies/nfv
[3] http://www.3gpp.org
[4] ETSI GS NFV 001 v1.1.1 (2013-10) Network Functions Virtualisation (NFV); Use Cases

These developments of virtualization led to the following business perspective:

- Multi-tenant telecom network provider, providing the hardware and communication links to service providers and enable them to exchange data. The hardware and communication links can integrate a variety of technology, e.g. mobile, fixed lines, and satellite networks. Network slicing is provided to offer a particular service to a network provider.
- Cloud providers offering storage and/or computational facilities.
- Software service providers developing and offering Network Functions and/or services like routing, firewalls, etc. These network functions operate in a cloud and integrate with hardware of telecom network providers via APIs.
- Service providers offering voice, data, video, and other types of network services to their users by orchestrating Network Functions that can operate in any cloud environment and manage and utilize underlying telecom networks of one or more multi-tenant telecom network providers.

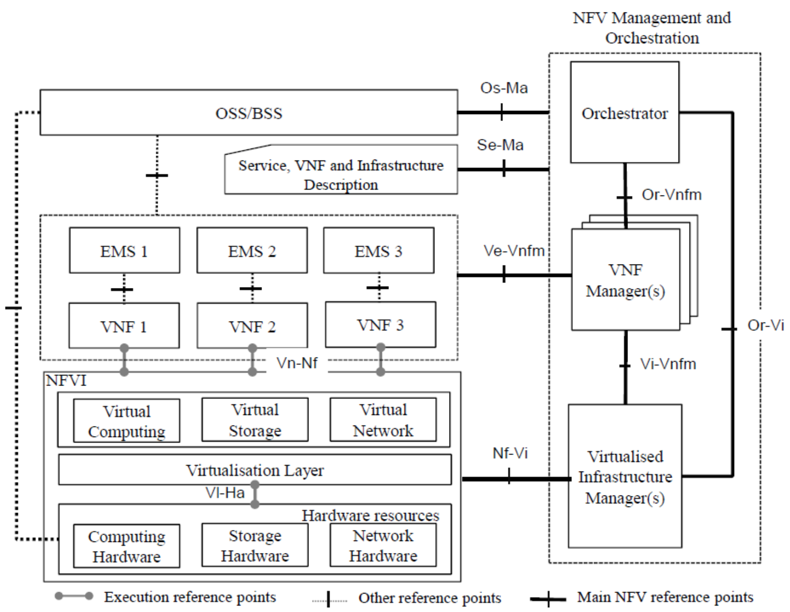

Figure 2: ETSI NFV functional architecture

ETSI NFV has defined a functional architecture for virtualized network functions[5]. Main elements are a virtualized infrastructure (NFVI), VIM (Virtual Infrastructure Manager), virtualized network functions (VNF) and their manager, and an orchestrator, which is intermediary between requests of services for connectivity, functions and computing resources. An Operational Support System (OSS) is required for management of operational use of a virtual network. MANO (Management And Network Orchestration), consisting of VIM, VNF Manager, and orchestrator, is a main element in managing and assigning resources and thus providing the services of a service provider to their customers. Upon receiving request for communication (and network functionality), it will contact VNF manager and VIM in order to reserve resources (communication links, processing and storage in data center) to fulfil that request. MANO will also instruct VNF manager to set up relevant VNFs and place them in already prepared processing and storage (already arranged).

[5] https://www.etsi.org/deliver/etsi_gs/nfv/001_099/002/01.02.01_60/gs_nfv002v010201p.pdf

A Virtual Infrastructure Manager (VIM) is an element in the NFV architecture which is crucial to facilitate the business perspective. It manages infrastructure elements, and constantly aligns requirements of service providers with that of multi-tenant telecom network - and cloud providers to assure the proper service level to end-users of the network providers. Furthermore, standardization is of the uttermost importance to be able to operate required network functions using hardware APIs. So, VIM is aware of availability of resources and (foreseen) resource requirements. The assumption is that cloud providers will have sufficient resources for deployment of the VNFs.

SDN and NFV offer advantages for both a multi-tenant telecom network provider and service providers. Former ones can make optimal use of existing resources, while service providers can focus on their core business without dealing also with networking aspects of their business. It will allow the implementation of innovative (expensive) assets compliant with (inter)national regulations in the infrastructure, like 5G, that can be shared by different service providers improving their service offering.

3 Applying network virtualization to supply and logistics

This section applies the virtualization of network functionality to the supply and logistics sector in a straightforward manner, meaning there is no analysis of differences. Firstly, potential roles and business models are explored and secondly, required functionality is described. The next section discusses differences.

3.1 Roles and business models

We can draw a parallel between supply and logistic and telecom networks by making a distinction between physical assets (‘hardware’) and required functionality to deploy this hardware for meeting customer demands (‘software’). Supply and logistics networks consist of assets functioning as resources with a particular capacity. Hubs with switching and (temporary) storage functions like terminals, warehouses, and cross-docking centers and physical infrastructure between these hubs can be compared with communication links, e.g. roads, inland waterways, and rail infrastructure. Since Physical Internet packages are physical, transportation assets like trucks and trains are required on these links, where the links are provided by public and/or private infrastructure managers.

Applying the concepts of SDN and NFV to supply and logistics, gives the following business perspective:

- Multi-tenant Asset Owners offer (network of) assets like hubs and transport means that can be utilized by many Logistics Service Providers. Hubs and transportation assets can be provided by different owners; the physical infrastructure used by the transportation assets is managed by private or public Infrastructure Managers or is not managed at all (e.g. oceans used by deep-sea vessels). Since all hubs and transportation assets will become autonomous, they need to have firmware with standardized APIs.
- Logistics Cloud Service Providers offer additional services like packing/repacking and stuffing/stripping (equivalent to computing services). They provide the so-called encapsulation layer (Ballot, Liesa, & Franklin, 2018).
- Software service providers developing all types of software-based services like dynamic chain planning, Estimated Time of Arrival (ETA) prediction, horizontal and/or vertical bundling, etc. These services can be compared with VNFs. Software service providers can have various business models like pay per use or monthly fee,

depending on the functionality. Cloud computing services and virtualization of these services provides resilience and sufficient computational resources to operate these services.

- Logistics Service Providers (LSPs) offer customer-oriented services for logistics. They have to specify their competitive advantage by for instance differentiation or lower costs (Porter, 1985). Differentiation can be on specific types of cargo, like containers or liquid bulk like oil, specific products requiring additional handling, like fruit, flowers, and livestock, or a focus on a particular customer market like eCommerce shipments. Differentiation might require also a cost focus, in case the competition is strong. Large distribution or postal networks have for instance a differentiation on eCommerce shipments, but might also be integrated in those eCommerce service providers.

The current logistics market is not yet organized according these four business roles. Some LSPs combine all roles to offer their services in a multimodal network, i.e. they are Asset Owner of transportation assets for different modalities (vessels, trucks, barges, trains), Logistics Cloud Service Provider (they have their own container stuffing centers), Software Service Provider, and LSP, whereas others only operate as LSP without any assets. Before becoming a multi-tenant Asset Owner, these former LSPs rather invest in the use of assets of other Asset Owners to increase their market share. Under the assumption that IT investments are relative low compared to investments in physical assets, many stakeholders develop their own IT solutions or adapt COTS (Commercial Off The Shelve) software to manage customer goods flows. This has created legacy with a high Total Costs of Ownership. Furthermore, most of them compete on costs, some have a differentiation focus.

3.2 Required functionality for supply and logistics

Similar to network virtualization, the following functionality is required in supply and logistics:

- Physical functionality consists of:
    - Links like roads, railways, inland waterways, and air traffic control.
    - Storage is represented by warehouses, logistics terrains, and hubs (the latter only for temporary storage).
    - Handling of cargo in cross-docking centers, distribution centers, as well as terminals.
    - Loading and discharging cargo from transportation assets.
    - Monitoring the quality of the cargo.
    - Management of assets like maintenance, positioning, and cleaning. These management functions are applicable to transport means and packaging material like containers and modular packages.
- Virtual Network Functions are services like:
    - Compliance services to validate cargo flows with regulations;
    - Dynamic planning for routing of cargo and (positioning of capacity of) assets.
    - ETA (Estimated Time of Arrival), ETD (Estimated time of Departure) and turnaround time prediction.
    - Bundling services to combine cargo flows.
    - All types of information services that may affect cargo flows like weather forecast – and traffic information services.
    - Traffic flow optimization services for cargo flow optimization in the physical environment.

  - Payment, clearing, and settlement services.

  A number of these VNF services can be built upon data analytics, e.g. deep reinforcement learning (e.g. dynamic planning, ETA/ETD/turnaround time prediction, bundling services, and traffic flow optimization), whilst others require a machine-processable representation (e.g. compliance rules, information services, and payment types of services). Developing data analytics based functionality requires training with large amounts of data.
- An Operational Support System (OSS) for monitoring and controlling cargo flows. It will need to show the actual status of cargo flows with special attention to exceptions (descriptive – , i.e. supply chain visibility, and diagnostic analytics). Examples of exceptions are (estimated) late arrival at the destination or arrival at another destination than the required one for cargo or a transport means. As VNF services control these exceptions, potentially goals of cargo flows need to be reformulated to meet customer demands.

A Registry is required for searching and finding the business services provided by stakeholders in the physical environment and the VNF for supply and logistics, similar to the one identified for the telecom environment.

Considering this layering, the Management And Network Orchestration functionality for supply and logistics will exist of:

- Virtualized Infrastructure Manager(s) that provide details of the Quality of Service (QoS) of a particular (subset of) the infrastructure, for instance road. The QoS will be affected by its predicted use and external factors like weather forecasts, but similar to retail, the QoS might also be calculated on past behavior.
- A Virtualized Network Function manager assuring the proper use of VNFs provided by external parties.
- An Orchestrator that creates a particular logistics network based on available assets, utilizing the various VNFs for supply and logistics. A specific focus will be given to creating a logistics network based on physical assets, since these will have to provide sufficient capacity to meet customer demands. The Orchestrator constantly monitors if demand and available capacity is matched, in coordination with the other management functions. This reservation can be at strategic -, e.g. quarterly based on predicted usage, or tactical level, monthly or weekly based on calculating the predicted time and costs required for the cargo flow using various business services provided by the physical environment.

The Orchestrator supports an LSP in creating it's logistics network based on physical assets and their available capacity. It can also imply that capacity can be shared between Orchestrators by one Orchestrator selling it's spare capacity to another. This type of orchestration can be compared with a Non Vessel Operating Common Carrier (NVOCC) that reserves capacity on vessels. New entrants like Flexport may also implement Orchestrator and OSS functionality.

These functions all require data as input to the various VNFs for supply and logistics. For instance, dynamic planning - and bundling algorithms provide the decision support that requires particular data. An open data sharing infrastructure is a prerequisite for functioning of the model. The following types of data are required for this type of decision support:

- Available business services and timetables spanning the network managed by an Orchestrator;

- (Short term) QoS of each of the legs and logistics activities of the network towards the final destination. This type of data needs to be provided by the Virtualized Infrastructure Manager.
- Details of short term availability of multi-tenant assets and a capability to reserve capacity of these assets for actual cargo flows. Availability of details of various cargo flows allows bundling of flows based on available capacity of assets and their services.

Decision support can consider aspects like costs, time, and carbon footprint. Mechanisms like slot management and dynamic pricing of slots can also be included to control flows.

4 Discussion

When drawing the parallel with telecom networks, the main difference of supply and logistics is the fact that cargo and assets are physical. Unlike information packages, cargo can get lost, cannot be resubmitted in case of loss, and assets have a limited capacity. Another difference is that information packages are only data, whereas cargo and transport means can have computational capabilities, i.e. they can be intelligent or (semi-)autonomous. Intelligent cargo implies that cargo can find its own way in the physical environment, via various hubs and with different transport means and – modalities. Finally, 'speed' is of another dimension in supply and logistics. Where seconds and minutes are of importance for telecom in transferring information packages, hours and days are considered in supply and logistics. These differences may lead to different implementations of VNFs, thus leading to other business models and – roles in supply and logistics compared with telecom.

We will discuss the parallel in more detail, both from a business and a functional perspective.

4.1 External drivers for change

The comparison between virtualization of telecom networks and supply and logistics networks clearly identifies current discussions within the logistics sector, namely should a logistics enterprise focus on becoming an LSP with or without physical assets.

Digitalization is the main driver of change supply and logistics, potentially towards these roles. Digitalization is at three levels: creation of autonomous assets (robotization), virtualization of IT functionality provided by new entrants acting as software service providers, and the introduction of eCommerce. Sustainability requirements formulated by authorities are an additional driver for change. These requirements may lead to new (inter)national and local regulations like city centers that are not accessible for some type of truck. These latter local regulations are already applicable.

There is an increase of robotization, covering aspects like loading/unloading cargo to transportation devices, fully automated terminals and warehouses, and creation of (semi-) autonomous transport means (trucks, barges, trains, vessels). These developments are bringing us a step closer to large scale fully automated logistic networks, operated by Multi-tenant Asset Owners. Extending this network with 'intelligent' π-containers, where these containers will have at least a sensor (IoT), but may also have (limited) computation power, even makes it possible to implement dynamic routing at package level. π-containers could have their goals programmed or refer to a so-called Digital Twin (Boschert & Rosen, 2016). Global operating shipping lines already invest in these types of networks by deploying fully automated terminals and investing in autonomous vessels.

The second driver for change is the development of innovative, software based services and multi-sided platforms. New entrants take the role of Software Service Provider by offer cargo bundling services (e.g. CargoStream), improve capacity utilization (e.g. TEUBooker), provide an overview of available services (e.g. Navigate), and implement an LSP as a multi-sided platform between customers and Asset Owners (e.g. Über4Freigth). These multi-sided platforms have already established a position in passenger transport, they will apply the same rules to freight transport with the potential implication they decide on the margin and the service performance of asset owners. Other new entrants implement a fully automated LSP, e.g. Flexport, and may potentially have a (primitive version of a) Orchestrator to assure they have sufficient capacity to provide a competitive customer service.

Besides last mile distribution and city logistics that impose challenges, eCommerce has given new entrants in supply and logistics on a global level. These new entrants have evolved from web shops, virtual shopping malls, payment providers, and IT cloud service providers to major logistics players. These new entrants utilize logistics stakeholders, especially in their role as multi-tenant asset owners. They can act as LSPs with functionality presented before.

It is yet unsure how the market will evolve, it can however be expected that (semi-)autonomous, programmable assets with firmware will require more investments, whilst authorities will impose increased sustainability demands, evolving into Multi-tenant Asset Owners. Intelligent algorithms will also evolve in mature services provided by Software Service Providers, thus forcing LSPs to focus on orchestration with similar functions like MANO for telecom providers. This required functionality will be discussed hereafter.

4.2 Future business scenario's and strategies

Based on the parallel with the telecom network sector, the following scenarios are feasible:

1. The telecom model. Supply and logistics is going to be organized like the telecom sector. It implies that VNFs are developed by independent IT providers, can interface with various physical assets, and can be applied by many LSPs. In this scenario, a distinction between multi-tenant asset owners and LSPs exists – LSPs don't own assets.
   We can observe two variants within this context that can be used by LSPs to create their supply and logistics networks:
   a. Intelligent hub network (Ballot, Liesa, & Franklin, 2018). Hubs implement the VNFs and optimize capacity utilization across the various links. They have access to data to optimize cargo flows. Such a hub network neatly aligns with the concept of so-called TEN-T corridors[6].
   b. Intelligent asset network. The VNFs are implemented by the assets, they are 'intelligent'. Even OEMs could develop and implement the VNFs and act as multi-tenant asset owners or they can provide their assets with on-board VNFs.
2. Multi-sided platform model[7]. Independent IT service providers establish multi-sided platforms with VNFs. Multi-sided platforms can function as intermediates of transactions between customers and multi-tenant asset owners, only if dynamic adjustments can be made automatically by (potential complex) VNFs supported by an open data sharing infrastructure (Ondrus, Gannamaneni, & Lyytinen, 2015). The success of these platforms also depends on its installed base (Kung & Zhong, 2017).

[6] https://ec.europa.eu/transport/themes/infrastructure_en
[7] See for instance: https://www.generixgroup.com/en/blog/platform-enabled-ecosystem-future-supply-chain

3. Mixed scenario. This one reflects the current situation, where we have LSPs with or without assets, hub operators acting as multi-tenant asset owners, carriers providing multi-tenant assets, and new entrants providing multi-sided platform services.

The mixed scenario can evolve further by individual enterprises developing VNFs and becoming fully vertical integrated enterprises. These enterprises will be able to fully optimize their operation and prevent any spill-overs (Hagiu & Wright, 2015). Global operating LSPs like this already exist; yet others try to develop this model. It is our expectation that those that strive for vertical integration require development of innovative VNFs based on data analytics, require collaboration with others to develop such VNFs. These VNFs can only be developed based on access to large amounts of data (see before). Multi-sided platforms face the same challenge if they want to evolve beyond intermediation of transactions.

It is our view that innovation in supply and logistics depends on development of VNFs and additionally OSS and MANO functionality for supply and logistics. Development of innovative VNFs requires data sharing and collaboration amongst competing stakeholders. We expect competition will be on the combination of OSS and MANO functionality – those that can optimize their logistics networks and cargo flows by using VNFs and multi-tenant asset owners will provided the required customer service. It is not feasible to construct this type of functionality in intelligent assets, since it requires a complete overview of cargo flows in a logistics network (OSS) and strategic – and tactical coordination of required capacity (MANO functionality). Intelligent hubs will also not be able to provide this type of functionality, since they have a subnetwork view.

5 Conclusions

Although there are differences between the telecom – and the supply and logistics sector, mainly driven by the physical aspect of cargo flows, the SDN/NFV paradigm may provide insights on how supply and logistics business roles and - models can change. These changes are mainly driven by digitization leading to new entrants and autonomous assets and increased sustainability requirements. Data sharing is a prerequisite to achieve the required changes and create large scale, efficient logistics networks, the Physical Internet.

Applying these SDN/NFV paradigm to supply and logistics may lead to various scenarios. We have identified three basic scenarios, with two sub-scenarios. Independent of any scenario, collaboration is required for developing innovative VNFs (Virtual Network Function) for supply and logistics and constructing a data sharing infrastructure. Competition will be on basis of developing a Management and Network Orchestration environment to meet customer demands, together with an Operational Support System (OSS) for controlling cargo flows.

One of the potential ways forward is to collaborative develop VNFs and an open data sharing infrastructure. The Digital Container Shipping Alliance (dcsa.org) is an example of such a collaboration. However, it requires the development of an IT architecture identifying all components (VNFs, OSS, MANO), an open data sharing infrastructure, and distribution of intelligence to multi-tenant assets like π-containers, transport means, and hubs.

We have taken the telecom sector as an inspiration for potential changes in supply and logistics, towards realizing the Physical Internet. Other sectors like energy and industry may also be relevant to explore. Energy is for instance changing towards distributed production; industry is exploring the use of 3D printing and robotization, where these autonomous assets also share their (predicted) capacity. Mobility as a Service, MaaS, may also provide an inspiration to supply and logistics, by comparing passengers with 'travel companions' representing Digital Twins of intelligent assets.

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