PROJECT MANAGEMENT & CONSULTING PRACTISE

Course Assignment

Abstract

The following is the full course assignment of the course Project Management & Consulting Practice as completed in December 2015.

N.N.,
Y.Y.

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PROJECT CHARTER 29.10.2015

Project Title: As-is and to-be -situations of VNaaS

Project Duration: 29.10.2015 **-** 4.12.2015

Budget Information: (2 h + 2 h) * 4 * 3,5 = 56 hours to use
PERT: (48+4*56+80)/6 = approximately 59 hours

Project Manager: Y.Y.,

Project Objectives:

Finding opportunities from VNaaS (virtual network as a service) and researching what kind of models have been proposed already.

Problem Description:

One of the major cost elements in Nokia's IT infrastructure is to ensure enough bandwidth and secure connectivity between Nokia sites and Nokia's partners. One solution to improve service level and cut the costs of the connectivity service including the bandwidth is to provide Network as a Service for Nokia units. Further, as a cause of rapidly changing market conditions, the research should be expanded to include new services that can be created on top of this NaaS concept.

Success Criteria:

Project will be successful if it provides insights that could help to realize the opportunities of VNaaS in context of the customer and leads to improved service level. This project should be completed on time and meet all of the requirements. The project customer and professor will determine if the project is a success or not.

Approach:

The project will take a market-driven approach in order to establish VNaaS role in the current and future landscape of network providers. Cross-validating this top-down approach with Nokia's current strengths will lead to a maximized probability of finding a sustainable, business viable solution.

First, an extensive study of literature in the field will be conducted and summarized in order to provide necessary contextual information. Cross referencing this knowledge, we will be able to pinpoint bottlenecks, challenges and opportunities of the rising NaaS environment. This naturally also extends to other ICT topics related to VNaaS and its environment, and we find it necessary for them to be covered in order to deliver a holistic view.

As a result of this project, we aim to deliver strategic know-how on the positioning on current and novel technologies and processes. For VNaaS we aim to provide insights on how this technology could be utilized for Nokia and its partners in an efficient manner. Our findings will be presented in a structured report with full referencing to information sources.

Project Team

Name & Student No.	*Role*	*Position*	*Contact Information*
	Team member	MSc student	
	Team member	MSc student	
	Project Manager	MSc student	
	Team member	MSc student	

WORK BREAKDOWN STRUCTURE

		Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1			**Nokia VNaaS Project**	**52 hrs**	**Thu 29.10.15**	**Mon 7.12.15**		**Joona (PM);Sam**
2			**Project design**	**9 hrs**	**Thu 29.10.15**	**Wed 4.11.15**		
3			Project charter	2 hrs	Thu 29.10.15	Thu 29.10.15		Jessica;Joona (PI
4			Brainstorming	1 hr	Mon 2.11.15	Mon 2.11.15		Jessica;Joona (PI
5			Scope	2 hrs	Wed 4.11.15	Wed 4.11.15	4;3	Jessica;Joakim;J
6			WBS and scheduling	1 hr	Wed 4.11.15	Wed 4.11.15	4;3	Jessica;Joona (PI
7			**Working phase**	**34 hrs**	**Thu 5.11.15**	**Tue 24.11.15**	**2**	
8			Research on present situatic	7 hrs	Thu 5.11.15	Fri 13.11.15		Joakim
9			Explaining inter-data center:	10 hrs	Thu 5.11.15	Tue 17.11.15		Joona (PM)
10			Explaining IoT trends and op	9 hrs	Thu 5.11.15	Sun 15.11.15		Jessica
11			Opportunities	7 hrs	Thu 19.11.15	Tue 24.11.15	8;9	Joakim
12			Future use	9 hrs	Sat 14.11.15	Mon 23.11.1!	8;9	Sampsa
13			**Project presentation**	**3 hrs**	**Wed 25.11.1**	**Thu 26.11.15**	**7**	
14			Making of the presentation (	5 hrs	Wed 25.11.1	Wed 25.11.1		Jessica;Joona (PI
15			Having the presentation	10 mins	Thu 26.11.15	Thu 26.11.15		Joona (PM);Sam
16			**Resource management**	**1 hr**	**Wed 2.12.15**	**Wed 2.12.15**	**2;7**	
17			Cost management	1 hr	Wed 2.12.15	Wed 2.12.15		Jessica;Sampsa
18			EVA	1 hr	Wed 2.12.15	Wed 2.12.15		Jessica;Sampsa
19			**Finalizing report**	**4 hrs**	**Wed 2.12.15**	**Fri 4.12.15**	**13;16**	
20			Edge computing, ammendm	1 hr	Wed 2.12.15	Wed 2.12.15		Joakim
21			Finalizing MS Project setup	8 hrs	Wed 2.12.15	Wed 2.12.15		Sampsa;Jessica
22			Compiling report	3 hrs	Wed 2.12.15	Wed 2.12.15		Joona (PM);Joak
23			Signing off the project	1 hr	Fri 4.12.15	Fri 4.12.15	22;21;20	Jessica

WBS

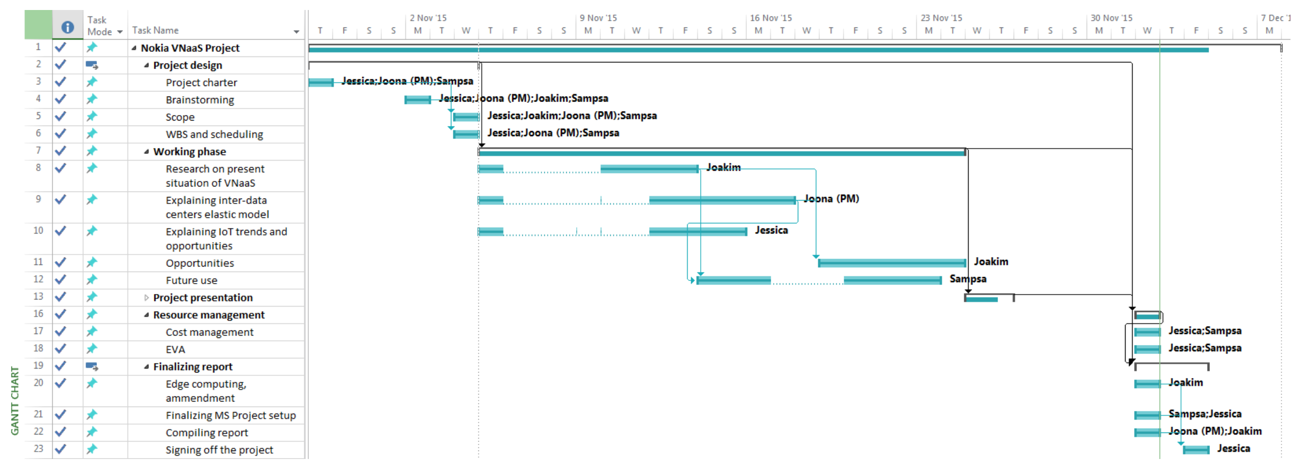
Our team decided to have 5 milestones, which are shown as bolded in the picture above. As we initially thought that we are going to use from 56 – 59 hours on this project, we tried to match the overall duration of the project (here 52) with our estimate. Because our workloads and working times were irregular we decided to make every day of the week a working day. We allocated every day 1 hour of working time and 1 hour more for Thursday and Sunday. By doing this the overall duration of the project was a close as possible our initial estimate. However, if we look at the actual duration of tasks, we see that their sum is 68 hours. And this doesn't include tasks where several people have been working on a task. When we count together all the tasks that have had two or more working on them the total duration of the project was 122 hours.

We had considerable difficulties in getting the times show correctly and eventually decided this was our best compromise. Bolded hours show our planned work and rest show actualized working hours.

SCHEDULING AND RESOURCE PLANNING

We estimated in the charter that we would spend about 56 to 59 and managed to get the program accept 52 hours as overall duration for the project. Project started on 29.10. and ended 7.12. even if we returned the assignment a bit earlier. While we were ready earlier, the 7.12. was a deadline given by the client and thus chosen as the de facto end date. We knew that the working phase will take us roughly 8 to 10 hours per person. What we didn’t realize was the demand from project design and finalization parts which both blew out of the initial budget.

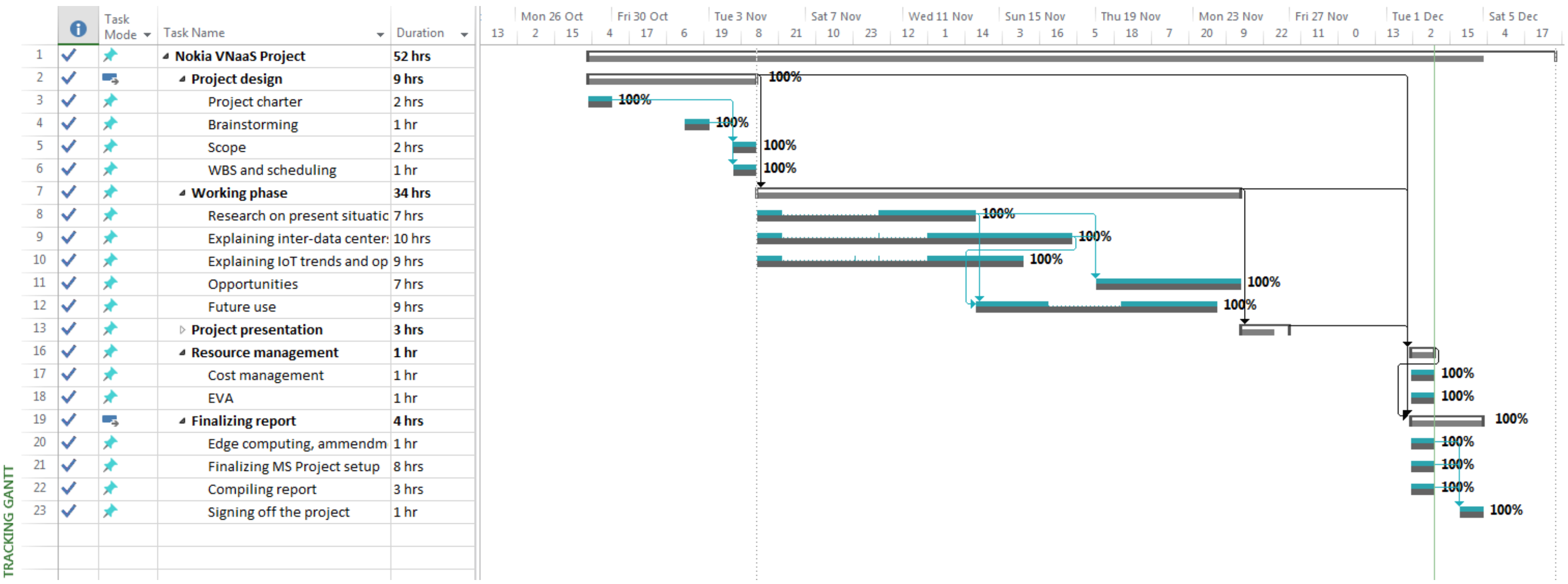
The project design part consisted of following parts: project charter, brainstorming scope and WBS & scheduling. Since the project was ill-defined and subject matter somewhat unfamiliar this phase took more time than initially thought. We first thought that this part would take us the Thursday’s (29.10.) lecture and then maybe bit more. As you can read from our diaries we spend considerably more time defining the scope and making the final adjustments to it.



Dependencies are depicted in WBS-picture as predecessors which essentially mean, that task cannot begin if the predecessor task is not completed. Our resources were mainly work (us) but as requested we also created material cost (binders for presentation) and cost (catering for presentation). Binders and catering were allocated into “Having the presentation” –task. We also added some fixed costs for tasks as requested.

	Resource Name	Type	Material	Initials	Group	Max.	Std. Rate	Ovt.	Cost/Use	Accrue	Base
1	Joona (PM)	Work		J		100%	24,00 €/hr	10,00 €/hr	0,00 €	Prorated	Standard
2	Sampsa	Work		S		100%	20,00 €/hr	5,00 €/hr	0,00 €	Prorated	Standard
3	Jessica	Work		J		100%	20,00 €/hr	7,00 €/hr	0,00 €	Prorated	Standard
4	Joakim	Work		J		100%	20,00 €/hr	6,00 €/hr	0,00 €	Prorated	Standard
							5,00 €		1,00 €	Prorated	
										Prorated	

	Task Name	Fixed Cost	Fixed Cost Accrual
1	Nokia VNaaS Project	100,00 €	
2	Project design	200,00 €	
3	Project charter	0,00 €	
4	Brainstorming	0,00 €	
5	Scope	0,00 €	



Tracking Gantt

Calculating the critical path would require that there are several ways to end up into the project target. However, in our case the project is extremely linear and though there are parallel processes within milestones, it is not possible to deviate from the path. The path was longer than expected but all the parts remained the same all the way. It is also not possible to skip any tasks. Thus, our critical path is same as WBS.

	Task Mode	Task Name	Duration	Start	Finish	% Comp	Cost	Work	Ad
1		**Nokia VNaaS Project**	**52 hrs**	**Thu 29.10.15**	**Mon 7.12.15**	**100%**	**6 568,35 €**	**298,33 hrs**	
2		**Project design**	**9 hrs**	**Thu 29.10.15**	**Wed 4.11.15**	**100%**	**644,00 €**	**21 hrs**	
3		Project charter	2 hrs	Thu 29.10.15	Thu 29.10.15	100%	128,00 €	6 hrs	
4		Brainstorming	1 hr	Mon 2.11.15	Mon 2.11.15	100%	84,00 €	4 hrs	
5		Scope	2 hrs	Wed 4.11.15	Wed 4.11.15	100%	168,00 €	8 hrs	
6		WBS and schedu	1 hr	Wed 4.11.15	Wed 4.11.15	100%	64,00 €	3 hrs	
7		**Working phase**	**34 hrs**	**Thu 5.11.15**	**Tue 24.11.15**	**100%**	**1 224,00 €**	**58 hrs**	
8		Research on pre	7 hrs	Thu 5.11.15	Fri 13.11.15	100%	220,00 €	11 hrs	
9		Explaining inter	10 hrs	Thu 5.11.15	Tue 17.11.15	100%	384,00 €	16 hrs	
10		Explaining IoT t	9 hrs	Thu 5.11.15	Sun 15.11.15	100%	300,00 €	15 hrs	
11		Opportunities	7 hrs	Thu 19.11.15	Tue 24.11.15	100%	140,00 €	7 hrs	
12		Future use	9 hrs	Sat 14.11.15	Mon 23.11.1	100%	180,00 €	9 hrs	
13		**Project presentati**	**3 hrs**	**Wed 25.11.1**	**Thu 26.11.15**	**100%**	**328,33 €**	**15,33 hrs**	
14		Making of the p	5 hrs	Wed 25.11.1	Wed 25.11.1	100%	320,00 €	15 hrs	
15		Having the pres	10 mins	Thu 26.11.15	Thu 26.11.15	100%	8,33 €	0,33 hrs	
16		**Resource manage**	**1 hr**	**Wed 2.12.15**	**Wed 2.12.15**	**100%**	**80,00 €**	**4 hrs**	
17		Cost manageme	1 hr	Wed 2.12.15	Wed 2.12.15	100%	40,00 €	2 hrs	
18		EVA	1 hr	Wed 2.12.15	Wed 2.12.15	100%	40,00 €	2 hrs	
19		**Finalizing report**	**4 hrs**	**Wed 2.12.15**	**Fri 4.12.15**	**100%**	**492,00 €**	**24 hrs**	
20		Edge computing	1 hr	Wed 2.12.15	Wed 2.12.15	100%	20,00 €	1 hr	
21		Finalizing MS Pr	8 hrs	Wed 2.12.15	Wed 2.12.15	100%	320,00 €	16 hrs	
22		Compiling repo	3 hrs	Wed 2.12.15	Wed 2.12.15	100%	132,00 €	6 hrs	
23		Signing off the	1 hr	Fri 4.12.15	Fri 4.12.15	100%	20,00 €	1 hr	

Budget

Getting a budget report out of the system proved out to be a challenge. Thus here is a table showing how the cost of the project is formed. How the software decided the overall price is a mystery as those bolded values sum up to 2768,33. The Project 2013 seems to think that almost 300 working hours was put into this project while the real amount is 122,33 hours calculated from “work” column. It is strange that the program calculates things correctly in parts but sums them up wrong. Since our estimated cost is 2768,33 we propose that we will have a budget of at least 3000,00 to have a small buffer for some force majeure events. Also less than 250 € increase in to projects price shouldn’t be a deal breaker for the client.

Project Statistics for 'Projectplan_nollaus.mpp'

	Start	Finish
Current	Thu 29.10.15	Mon 7.12.15
Baseline	Thu 29.10.15	Mon 7.12.15
Actual	Thu 29.10.15	Mon 7.12.15
Variance	0h	0h

	Duration	Work	Cost
Current	52h	298,33h	6 568,35 €
Baseline	52h	298,33h	6 568,35 €
Actual	52h	298,33h	6 568,35 €
Remaining	0h	0h	0,00 €

Percent complete:

Duration: 100% Work: 100%

Close

COST OVERVIEW

THU 29.10.15 - MON 7.12.15

COST

6 568,35 €

REMAINING COST

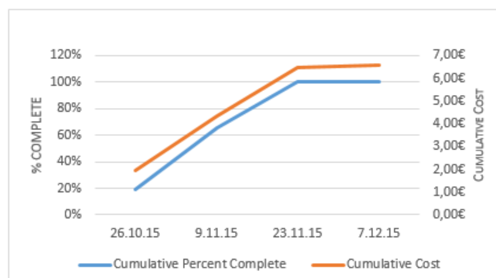
0,00 €

% COMPLETE

100%

PROGRESS VERSUS COST

Progress made versus the cost spent over time. If % Complete line below the cumulative cost line,your project may be over budget.



COST STATUS

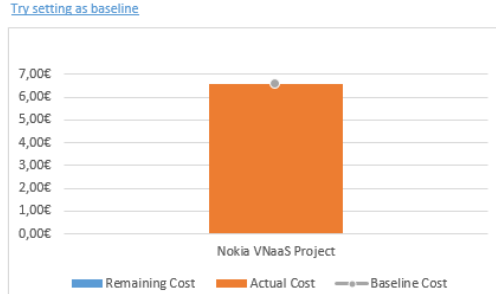
Cost status for top level tasks.

Name	Actual Cost	Remaining Cost	Baseline Cost	Cost	Cost Variance
Nokia VNaaS Project	6 568,35 €	0,00 €	6 568,35 €	6 568,35 €	0,00 €

COST STATUS

Cost status for all top-level tasks. Is your baseline zero?

Try setting as baseline



We didn’t manage to get proper EVA-report out of the system. However, this cost overview functions as a mirror to it. EVA essentially shows how much we have billed and how much there is to bill. In our case it shows us the costs incurred and how much we are expected to incur in the future.

CONSULTING PROPOSAL

Executive Summary

In this report we present our research where we thoroughly examined key concepts such as e.g. software defined networking, internet of things, virtual networks as a service, elasticity as a service and edge computing. We also researched market dynamics and present opportunities, challenges as well as likely future development.

Our approach is strongly market-driven, to ensure our recommendations are plausible with respect to the business environment. We have also tried to imply a good-fit of Nokia’s current capabilities with challenges that arises with the emergence of novel technologies and trends.

We found that the main and most pressing challenge is the exponentially growing amount of data and data transfers, that is only expected to grow even more rapidly with the full enrollment of IoT and following Machine Type Communication, along with increasing demands on ultra-low latency for certain niches. The demands on network capacity and bandwidth are now growing at such a fast pace, that a single disruptive technological revolution is unlikely to solve the problem. Market consensus seems to imply an evolutionary process, where legacy systems are built upon and utilized more efficiently through novel technologies and the infrastructure itself is renewed slowly. This implies that the new landscape will be defined as a system-of-systems, rather than a single systems. Market players are currently in close co-operation to ensure standardization in these processes.

In order to meet these challenges, opportunities arise as novel technologies are adopted and new concepts formed. As the need for capacity exceeds that which can be offered through traditional fixed offerings, new service models are proposed. Virtual Networks-as-a-Service and Elasticity-as-a-Service are to play key roles in utilizing existing infrastructure in order to keep up with growing and fluctuating capacity demand. Technical innovations that will allow this landscape are Software Defined Networking, Mobile Edge Computing and full-virtualization. To ensure full flexibility, the landscape is going towards a fully programmable world.

We suggest that Nokia takes a spot right in the middle of this landscape, where complexity reaches a maximum, and acts as a broker of network capacity. Thus, adding value through reducing complexity and enabling the transfer of capacity between parties, as capacity shortcomings most likely will be an issue in the future. This is done by utilizing full-virtualization, full-programmability and inter-datacenter EaaS to match network capacity to network needs seamlessly and automatically.

We believe this position is a good fit with Nokia’s extensive know-how and existing relations to key partners and fill an important function in an environment that grows more and more complex. It is also a good position to be in as network capacity goes towards a utilities-type of market. Moreover, this position, once established, is hard for competitors to get in to as the stickiness of customer loyalty will be exceptional once Nokia is the go-to broker administrating network capacity.

The report will first explain key concepts and how they relate to the landscape as a whole. Then, we describe the likely development of the landscape in the coming 10 years and what opportunities arise with this development. Following this holistically organized text, we take a look at monetization and pricing models for bandwidth-on-demand. We finish off the report with a summary and a short list of key-points.

VNaaS and its Role in Future Networks

Virtual networks are a type of network where at least a part of the network links are virtual, which allows multiple virtual networks to coexist over the same physical structure in a seamless manner. A network virtualization environment is an environment that enables multiple network architectures by sharing the same infrastructure resources. In this environment, virtual nodes and links are mapped to nodes and paths of a substrate network. [3]

The following is a summary of Carapinha's discussion on scenarios where VN could be implemented and problems with these scenarios. [4]

In scenario A the virtual network operator selects and establishes a direct business relationship with infrastructure providers. This is typically the case if the virtual network is based on a single or on only a few infrastructure domains, but as the number of infrastructure domains grows it might grow to be complicated to handle.

Scenario B overcomes the limitations of scenario A by introducing virtual network providers, an intermediation role between the virtual network operators and the infrastructure providers. The virtual network provider is responsible for finding the network resources at the best possible and offering them to the virtual network operators to configure the virtual networks. The main advantage of scenario B is that it enables virtual network operators to roll out large virtual networks without having to deal with the potentially complicated set-up situation with many infrastructure providers involved. However, the introduction of virtual network providers introduces another layer and therefore adds to complexity. We believe this scenario to be the most likely today.

In the last scenario, scenario C, the set-up situation follows the same structure as in scenario B only that the virtual network providers step out of the picture after finding and introducing the infrastructure providers, so that the virtual network providers essentially acts as brokers. The advantage here lies in avoiding the excess link that is present in scenario B, but on the other hand makes responsibility of quality control more confused.

He also identifies four main issues with large scale VNaaS. The first being reliability, as virtualization adds an extra step of complexity, it adds an extra potential for failure and is something that must be taking into account before large scale rollout of virtual networks. The second is interoperability. He suggests that a standardized approach is needed to tackle the challenges of interoperability between different heterogeneous domains. The third issue is presented as that strict isolation of link resources cannot be guaranteed, even if computational resources can. The last issue he describes is that it is "difficult and probably impossible” to find a unique model to describe the inter-relationships between network virtualization players, which is likely to further complicate the standardization of interfaces. Further, he also lists several other issues related to virtual networks being operational complexity, quality management, programmability, accountability and monetization.

He further elaborates on the possibilities in these scenarios, painting a picture of network resource and bandwidth going towards a utilities-type of market where they are fully separated from the underlying infrastructure. As network providers are separated from underlying infrastructure in a programmable world, the market would open up for a range of new players hosting these new, highly-customizable networks. The key to success for virtual network players here becomes organizing resources as efficiently as possible to match the specific use cases that arises with current trends. The advantage of offering virtual networks as a service also lies in their high customizability and the possibility to quickly set-up and take down virtual networks to match demand and requirements as closely as possible. [4]

Elasticity-as-a-Service (EaaS)

Definition and introduction of Elasticity-as-a-Service

In the context of virtual networks elasticity-as-a-service (EaaS) can be interpreted as a way to quickly scale bandwidth input or output automatically in a large-scale cloud computing environment if there are workload fluctuations that vary in time [11][12]. Cloud service providers (CSP) need to estimate and have a pool of network resources reserved that is required to meet the demand of network workload fluctuations that is caused by the applications using the cloud service. Fluctuations are caused mostly by the type of offered services or other possible external events that result in a spike or gradual growth in bandwidth use. [3] Thus cloud services are under constant dynamic variance therefore making virtual network elasticity and extensibility crucial to meet the set service level objectives (SLO) [13].

To be able to predict traffic load fluctuations and to ensure the fulfillment of SLOs of distributed cloud-based applications, a new approach has been introduced to use inter-data centers network EaaS at differentiated levels instead of just focusing on efficient and dynamic allocation of network and computational resources within data centers. Existing approaches have led into ineffective use of resources due to these existing solutions’ nature to provision unbounded resources or have static provision of expected peak-traffic value. With this new approach CSPs can automatically scale hosted applications’ spent resources in an efficient way. Modeling of inter-data centers traffic workload is done using Markov chain model, which offers significant advantages in complexity analysis, scalability and time compared to other modeling techniques. [3]

Opportunities in using inter-data centers

This new approach of inter-data centers network resource management is able to do dynamic re-sizing of inter-data centers bandwidth pools to guarantee sufficient availability of network resources and to meet the required level of network EaaS. By taking this new approach in use, CSP can estimate needed network resources that have to be reserved by calculating a pre-defined elasticity level for each distributed cloud application. Therefore it is possible to categorize applications by their type to different EaaS classes and then define what elasticity level to offer each application from perfect (almost unlimited bandwidth) to partial (resources guaranteed to certain level) elasticity level. Thus, with this new inter-data centers network resource management approach leads to better understanding of cloud applications' attributes and sufficient EaaS pool size can be estimated more precisely which makes fluctuation forecasting more accurate in order to fully take advantage of network capacity's financial potential. [3]

It is also possible for CSPs to introduce dynamic pricing model after taking inter-data centers EaaS in use. This way they can maximize their expected long-term revenue by being able to use this new model that is tailored for the dynamic nature of cloud traffic workload which uses the whole network capacity potential in contrast to static pricing model that has fixed contracts. With this new dynamic pricing model it is easier to compare the revenue cumulated of providing EaaS and the expected income from selling the extra network capacity against the estimated optimal long-term revenue. Hence, CSPs are able to make more informed decisions whether to save the network capacity to meet EaaS demands or sell it. There are also implications that if the client's elasticity class is high, the more bandwidth demands are met at a higher price. All in all, using EaaS in virtual network context opens the possibility for CSPs to offer sufficient bandwidth elasticity levels for multiple stakeholders that use the cloud's capacity in a profitable way. [3]

Internet of Things

Defining the Internet of Things paradigm and the content

In short, Internet of Things (IoT) is a merging, worldwide Internet-based network of interconnected objects. Wireless Sensor Network (WSN) technologies enable ubiquitous sensing which creates the IoT in a communicating-actuating networks. Sensors and actuators mingle with the surrounding environment, and the information gathered is shared across platforms to develop a common operating picture. The purpose is to provide a secure and reliable IT-infrastructure to facilitate the exchange of objects. [8]

IoT aims to combine embedded, intelligent devices and data analytics combined with businesses to enable new business models and competitive, user-centric services. The model consists of services that are similar to traditional products. Because of the cost-based model enabled by cloud computing provide end-to-end services for businesses and users to access applications anytime and anywhere. According to Gartner's IT Hype Cycle IoT is an emerging technology and will take 5 to 10 years for market adoption. [8][10]

IoT needs a shared understanding of the situation of users and their usages, software architecture and communication networks to process and pass on the relevant information to where it is needed, and analytical tools that aim for autonomous and smart behavior. This will lead to disappearance of the technologies from the users' conscious environments. The computing paradigm has to go beyond traditional mobile computing scenarios into connecting the everyday objects and embedding intelligence with our environment to ensure the IoT vision to success. The three components of the IoT are hardware, middleware and presentation. Hardware consists on sensors, actuators and embedded communication hardware, such as Radio Frequency Identification (RFID) and WSNs. Middleware includes tools for data analytics as well as on demand storage. Presentation is made up of visualization easy to understand and interpretation tools which can be accessed on different platforms. [8]

Challenges

IoT also brings challenges for example in security, privacy, and participatory sensing and data analytics. Security is always a huge concern when networks are used at large scale. Especially when businesses are concerned, IoT has to be highly reliable. It has to be resilient to attacks through self-adjusting to avoid failures. Against outside attacks encryption ensures confidentiality and message authentication codes ensure integrity and authenticity. Against inside attacks, however, non-cryptographic means, such as periodically reprogramming of all nodes, are needed. [8]

Privacy includes personal information concealing and the ability to control this information. Customer privacy is a very important matter always when data is collected and shared. Privacy Enhancing Technologies (PET), for example virtual private networks and onion routing, are developed to achieve these requirements. Virtual Private Networks (VPN) such as extranets are created among different business partners. Onion routing means that data is concealed with multiple encryption layers. Peer-to-Peer (P2) systems can also be used to increase security and privacy. [9]

It has been suggested that to ensure resilience to attacks, data authenticity as well as access and privacy control, a legal framework has to be created by an international legislator. [9]

New technology: Power over WiFi system

University of Washington engineers have created a novel technology that could help to develop the Internet of Things. The Power over Wi-Fi (PoWiFi) system power energy-harvesting sensors and devices with the help of existing Wi-Fi chipset which is something nobody has demonstrated before. Popular Science has included this system to its annual “Best of what’s new” awards. [22] [23]

Wi-Fi router is a wireless communication infrastructure and a ubiquitous in indoors. It runs in the ISM (Industrial, Scientific and Medical) band so transmissions can be modified to deliver far-field wireless power without significant impact on the network performance. Because of Wi-Fi’s economies of scale, Wi-Fi chipsets are cheap platforms for sending power-optimized waves which can be used to efficient power delivery. In general, a router with PoWiFi imitates a continuous transmission and minimizes the impact on Wi-Fi performance at the same time. This is done by injecting small amounts of unintrusive power traffic on multiple Wi-Fi channels to increase channel occupancy. [22]

Many sensors and mobile devices have already 2.4 GHz antenna that can be used for both communication and deliver Wi-Fi power but the power-delivery efficiency depends on the traffic of the router and other Wi-Fi networks which was analyzed in this deployment. This was tested with a low-resolution grayscale camera, a simple temperature sensor, and Jawbone activity tracking bracelet as well as deploying the system to multiple homes. Results show that a battery-free camera sensor prototype operated up to around 5 meters away from the PoWiFi router, and in the same manner a battery-free temperature sensor prototype operated up to around 6 meters away. PoWiFi can be used also as wireless charger for devices like FiBit and Jawbone activity trackers. In the test, a USB charger was connected to Jawbone device and the PoWiFi router was placed right next to them. In 2.5 hours the device was charged to 41 % from no-charge state. In home deployment, where 6 different households used the PoWiFi router for their Internet access for 24 hours, nobody didn't notice any effects on their web performance though power was delivered at the same time. [22]

Although so far only small amounts of power has been harvested through experiments mentioned above, the engineers believe that the PoWiFi system could be develop more efficient and robust. When considering the IoT, one key issue is how to power small computing sensors and devices embedded to everyday objects. Because they are becoming smaller and more numerous than before they cannot be plugged in to provide power which is also very difficult at large scale. With PoWiFi system power could be delivered efficiently via real-world Wi-Fi networks. [22] [23]

Edge Computing

Edge computing, or mobile edge computing (MEC), offers cloud-computing capabilities and IT capabilities within the radio access network (RAN). This environment is characterized by high-bandwidth and low latency. [14][15] Practically this means that MEC side-steps the issue of data transferring and centralized computing, which has the possibility to greatly reduce stress on centralized networks and computing centers and additionally provide new opportunities of an ultra-low latency environment.

Don DeLoach lists no less than seven reasons why MEC is critical to the development of IoT in his blogpost on July 10, 2015 [16]. The first is that MEC can reduce the amount of data having to be transferred, since computing is done on the edge – only valuable information is sent out from the edge. The second reason he lists is the ultra–low latency environment it provides for latency sensitive use cases, such as automated driving. Next is configurability, as he argues that sensors can be smaller, simpler and cheaper by only having one lPv6 address, to an edge device that then can be configured. Security is also mentioned, even if there are arguments on both sides as to whether or not MEC makes the environment safer. As the fifth reason, he lists data governance which is likely to be made easier since computing is handled on the edge. The sixth reason is architecture, as he believes market demands will push systems design to "allow for the abstraction of the ingestion of the messages from the utilization of that data". The last reason is simply cost, since MEC can reduce data traffic significantly for use cases with high exhaust rates.

MEC provides a new ecosystem and value-chain. By opening up RAN edges to authorized third parties, innovative applications and services towards mobile subscribers and vertical segments can be applied in such a fashion that all players benefit from higher cooperation. [14][15]

A new MEC industry specification group (ISG) has been appointed within the European Telecommunication Standards Institute (ETSI) to deal with the issue of creating "a standardized, open environment which will allow the efficient and seamless integration of applications from vendors, service providers, and third-parties across a multi-vendor Mobile-edge Computing platforms" as proposed in the industry white paper "Mobile Edge Computing – Introductory Technical White Paper". [14][15]

As summarized on ETSI’s web pages: “MEC will enable applications and services to be hosted ‘on top’ of the mobile network elements, i.e. above the network layer. These applications and services can benefit from being in close proximity to the customer and from receiving local radio-network contextual information.”

Introduction to Future Networks

In the 21th century, we have seen an explosive growth in mobile data expanding further from human-to-human (H2H) communication to heavier types of data transferring such as online gaming and video streaming services. Novel technologies and adaptions have had to been developed to facilitate the new requirements on mobile bandwidth as users are enabled to access data heavy information such as video, music and UHD on the go. In the light of this, the 4G network was launched, primarily designed for high speed mobile broadband [1]. Today, however, existing technology will not be enough to couple with the increasing demands on networks.

As of today, we see again a change in the environment as the internet of things (IoT) is taking off. With the introduction of machine-type-communication (MTC), and specifically machine-to-machine (M2M) communication that is expected to surpass H2H type of communication in time, we are again facing new requirements on network capabilities. With big data only getting bigger, networks are expected to maintain any-to-any connectivity without breaking down on latency.

As the IoT expands and becomes creates an “internet of everything” where everything is connected, H2H communication will be reduced to a small fraction of the data transfers that happens in our networks, with humans being only on the surface of this mass of new data. As devices get smarter, MTC will put heavy requirements on flexibility, mobility and interoperability of networks and layers. One example of this would be automated driving or driving support that has already rolled out in Tesla models. By imagining all cars in New York using automated driving simultaneously, one can imagine the stress that will be put on local networks. To achieve non-existent latency and accuracy, all these will have to use local routers and communicate with each other as well as a central network, all on top of other types of H2H communication and other MTC.

While flexibility and mobility requirements are fairly straightforward to design into systems, the interoperability requirement is the one that forces us to take on a more holistic view on the architecture of the future internet, to be able to handle diverse use cases with the same underlying systems and resources. Nokia’s view is that a future 5G network should be designed as a system-of-systems, to ensure these qualities. [1]

How do we support the requirements on future networks?

The following is a summarization on Nokia’s views according to their white paper “5G – a System of Systems for a programmable multi-service architecture”.

The first thing we need to ask ourselves is:” Can the current Evolved Packet Core (EPC)/System Architecture Evolution (SAE) efficiently support the services of the 5G era?” The answer to that would clearly be no. Earlier mentioned requirements on ultra-low latency and full mobility are not going to be met on current LTE and EPC architectures and adding the diverse applications that have to be handled on the same system makes it clear that our current 4G networks, primarily designed for high-speed mobile broadband, are not going to handle future requirements.

The challenge here becomes to design a single system of systems that can meet all these requirements invisible from a user perspective. Challenges here are to keep complexity and cost to a minimum. While costs can be cut by using already existing infrastructure more efficiently through new adaptions of technology, a unified approach must take place to keep complexity down for market players.

As complexity increases with the diversity of user cases, one must adapt new technologies to fulfill requirements on flexibility, scalability and automatization. By adapting the views of a programmable world, these requirements can be fulfilled by adapting network function virtualization (NFV) and software defined networking (SDN). [1] (*Nokia white paper stop)*

SDN and NFV are two of the most promising concepts that are set to bring innovation in the networking landscape with current SDN efforts starting from the consideration that, by providing full visibility of the network from a logically centralized controller, it is possible to simplify network control and management tasks [2]. NFV consist virtual machines running software and processes on top of infrastructure, instead of having hardware appliances for each network function.

(*Nokia white paper continues*)
To support new business models the traditional ‘one size fits all’ network architecture needs to change to a ‘flexible per service’ paradigm, in line with service oriented architecture (SOA) views. As we strive for a fully programmable and virtualized world, with access, core OSS, security etc. virtualized, it should be possible for operators to create entire networks virtually. The programmability of these SDNs ensures the flexibility needed of the future internet.

Nokia’s view is that this type of change cannot, and should not, happen overnight and a phased approach is proposed. The first phase is solving current business needs to boost mobile broadband capacity and tightly connecting 5G radio access to the 4G network via dual connectivity. The second phase introduces an optimal architecture for massive MTC, critical MTC and extreme mobile broadband. Here, network slicing through network virtualization will allow network resources to be tailored to the needs of the application and capabilities of devices in a programmable landscape. It is in this second phase VNaaS has a key role in defining the business landscape. [1]

Opportunities and applications for IoT and VNaaS

The number of interconnected devices are expected to reach 24 billion by 2020, which equates to $1.3 trillion revenue opportunities for mobile network operators alone [8].

IoT provides new evolving data and computational resources needed to create revolutionary apps. Consumers may choose the wanted service level by changing the Quality of Service (QoS) parameters. Cloud-based IoT is flexible, open and user centric, and enables different parties to interact seamlessly in the IoT network. [8]

Data is seamlessly shared between different service providers, and this creates many business opportunities. For example, Personal IoT produces data about electricity usage of the house, and the electricity company can analyze this data and optimize the supply and demand of electricity in Utility IoT. Smart grid and smart metering are also Utility IoT application aiming to optimize the energy consumption through continuous monitoring. In a city scale, this information enables maintaining the load balance and ensuring high quality of service level. It can also help in water network monitoring to ensure high supply quality and to prevent accidental contamination, but it can also be used to monitor irrigation in agricultural land. [8]

In a work environment, environmental monitoring is the first common application aiming to track the number of occupants and to manage the utilities such as lightning. Transport IoT with large scale WSNs, enables smart transportation and smart logistics by monitor travel times, queue lengths and air pollutant online and also helps to plan transportation routes. [8]

IoT enables ubiquitous healthcare by using body area sensors from where the data is uploaded to servers. This can be done, for example, with smartphones measuring physiological parameters. Elderly care may also be changed through a home monitoring system where the doctor monitors patients and the elderly in their own homes. This enables early intervention and treatment, which again lead to reducing hospitalization costs. [8]

The great opportunity of virtual networks and their offering as a service lies in the deep customization possibilities of networks to match the ever increasing number of user cases. Virtual networks need to be matched to broadband, massive MTC and critical MTC needs. This model also creates opportunity to more efficient pricing, since it allows for billing the resource users, and not as of today when the ones using the most resources get them comparatively cheaper than users with low resource needs.

One challenge that remains is for virtual network users to accurately estimate their fluctuating need of capacity as peak-traffic loads of each virtual network. Virtual network users would need to be able to demand the right amount of network resources to ensure quality of the applications hosted while still keeping as little excess resources as possible to ensure infrastructure is utilized as much as possible. [4]
With this type of problem, there is also an opportunity. By offering a value adding service to increase network capacity on demand. This concept, elasticity-as-a-service (EaaS), can further improve the utilization of network resources as the demand for network capacity is not perfectly correlated over time. In other words, this is yet another way to offer the same resources to several customers.

As VNaaS starts to tailor virtual networks to user needs, there will be an ocean of differentiated networks available. This new market will also open up for connectivity-as-a-service, CaaS. Ben Edmond, Chief Revenue Officer at Global Capacity is stressing the need for multiple-location businesses to have access to reliable, flexible and cost-effective network solutions. In his opinion, traditional corporate networks can no longer meet the needs of modern enterprises and thus, a flexible and secure hybrid network should be adopted such that it may grow with the business needs. [5]

To summarize, great opportunities are coming for network players as we enter the era of the internet of everything, where everything is connected and MCT makes up most of the communication even anticipating human needs and creating a ‘sixth-sense’ for end users [6]. With quickly changing user needs comes the need for great adaptability, which can only being achieved by a fully flexible and programmable world. Software defined networking and network function virtualization are key concepts that will drive this change towards the future of networks [7]. Key challenges, besides the technical, is managing complexity in this new world. A non-disruptive approach towards a common goal have already been proposed by several market players. [1][6][7]

Summarized, future connectivity must support far more use cases than in the past. NFV and SDN are underlying principles for improving usage efficiency and building an adaptive and programmable multi-service architecture. NFV and SDN also creates an optimal playground for new VNaaS providers, as these virtual networks can be tailored to match the needs of user cases and geographically distributed or cloud resources.

Table 1. SWOT of Landscape

Strengths	**Weaknesses**
• Better usage level of hardware • Flexibility of networks • Mobility • Programmability	• Legacy systems / non-compatible systems • Long investment cycles of legacy infrastructure
Opportunities	**Threats**
• Lots of room for business models in niched VNaaS, CaaS, etc. • System-of-systems allows for evolutionary development leading to more stable market conditions	• Managing complexity • Downwards price pressure on network-as-commodity • Security • Breakdowns, hard to know what will happen in large interconnected systems

Business, Monetization and Pricing Models for Bandwidth-on-Demand

Monetization Models

In their white paper about monetization of Internet of Things Capgemini comes up with four monetization models that depend on the relationship between customer and complexity of the IoT model. Ecosystem Building essentially means that Nokia would create a platform that would provide standardized working environment for hardware and software developers and charging money for the use of the platform. One of Finland’s most remarkable economists Matti Pohjola noted in a panel discussion 16.11 that at present there is fierce battle over which platforms and standards become used worldwide. Thus the time to act is now, if Nokia wants to build its own ecosystem. In the past parties providing technical platforms have made customers and users tied to their own technology, this time however, the platform must be as open as possible and limit as little as possible.

Hardware Premium means exactly charging a premium for the products ability to function in IoT ecosystem. Simple example would be a refrigerator that tells via SMS that the door is open or that the temperature is suboptimal. Service Revenue model would mean that company attempts to gain recurring income from selling a service (and bundling them) instead of a traditional product. An example could be changing maintenance service from physical checkups to model where the machine notifies automatically when there is need for repairs or even before that. Data revenue instead means that companies like Nokia that own the infrastructure collect, aggregate and anonymize data and sell it forward to offer insights for its customers.

For BoD the most fitting model would be Service Revenue. Instead of customer having to negotiate for the extra bandwidth in real life, Nokia could as a broker offer extra bandwidth automatically. However, offering bandwidth would inevitably lead into confrontation with agents such as Amazon. Since there are currently no proper standards for IoT and the various existing IoT solutions work poorly together due to complexity of very different technologies [19][20][21]. Thus a viable strategy for Nokia Networks would appear to be creating an ecosystem that enables IoT-device manufacturers, application and service developers to work in an environment that takes care of compatibility issues.

Table.2 Monetization as per Capgemini

Monetization models	
Ecosystem Building	*Company creates a platform where they hope to attract hardware manufacturers, software developers and end consumers- At present software work poorly with 3rd party software*
Hardware Premium	*Company charge premium for products capability of network connection*
Service Revenue	*Company transforms a traditional product into service*
Data Revenue	*Company gathers data from sensors, agglomerates it and sells onward as insight*

Pricing models

In the table below there are 8 pricing models proposed for IoT monetization. Three of them are straightly related into ecosystem building, but we also examine pay-for-results and subscription. In Pay-for-results model the customer pays according to results gained i.e. if we were to compare the IoT-platform to Google Store, how many customers are downloading the program, application or service that functions in the platform. In subscription model the customer pays monthly, quarterly, daily or whichever period is chosen for the use of the platform. Subscription differs from fixed fee in that regard that in subscription customer is allowed to modify what kind of platform's feature he or she buys.

In fixed fee model the customer pays certain figure for the use of the platform. This is very rigid solution and thus not very optimal for either party. Transaction based pricing would mean that Nokia as a platform maintaining party, takes a fee out of every transaction that happens in their platform i.e. downloaded services / applications. In revenue share model the Nokia would take certain percentage of the revenue the customer has generated in Nokia's platform.

In Bandwidth on Demand contracts following just on kind of a pricing model usually leads into suboptimal solution for both parties and thus hybrid models are preferred. Usually there is small fixed fee and rest of the bandwidth is invoiced with some pay-as-you-go criterion such as amount of traffic (in GB's) or GBs / unit of time. [18] Same kind of a hybrid model should prove fruitful for the ecosystem billing. Charging the customer for a small fixed fee few times a year and supplementing the model with either transaction or revenue model will provide more optimal solution for pricing than any of these models alone.

Table 3. Pricing models

Pricing models		**Applicable monetizing model**
One-time Charges	*Consumer pays once when purchasing the offer*	
Pay-for-Results	*Consumer pays only realized results from Io.*	Hardware Premium, Service Revenue, Data Revenue
Freemium	*Service is provided free of charge but additional features are not free*	
Subscription	*Allows the customer to customize their service, length, features etc.*	Service Revenue, Data Revenue
Pay-As-You-Go	*Customer pays according to the actual use of service.*	
Fixed Fee	*Customer pays fixed fee for the use of the platform*	
Transaction Based	*For every transaction the provider takes a percentage as reward*	Ecosystem Building
Revenue Share Model	*Customer pays a portion of revenues for platform provider*	

Business case

To address the question why should Nokia create this ecosystem let's compare it to a Google's Play Store. Play Store is a place (strictly speaking not a platform, but very analogous) where applications for mobile devices are sold and where almost anyone can sell their products. Google offers a market place and acts as a liaison between consumers and producers. Producers know they can sell their application easier through Play Store than on their own sites as Store's selling point can be thought to be trust. Consumers can trust that applications they buy from the Store may not function 100 % perfectly, but they are free of viruses.

In a same way Nokia can create an environment where producers and buyers can meet up. The task however, is much more complicated and daunting. Developers don't want to get tied down to a certain technology and since IoT is relatively new, new technologies and application will arise. The carrot for developers to use Nokia's platform could be the standards. If the developer follows certain standards it can have access to the platform and thus market that I couldn't otherwise reach.

Then again, consumers (business or consumers) don't want to have 12 different controlling applications for their IoT products. By providing compatibility Nokia can attract these kinds of customers as more devices can be controlled with same application. For consumers the selling point could be that what they buy from Nokia's platform is compatible with their other devices and applications. This way Nokia could also re-enter the consumer markets should it choose to do so.

As creator and maintainer of the ecosystem Nokia could bill the producers a fixed fee for entering the platform and charge either from profits or transactions. It could also charge the end users a subscription fee for using their platform. Of course particularly consumer billing mustn't be so expensive as to drive a way consumers. The more end users the platform has the more Nokia can charge the producers as they may have no other option to sell their products.

Summary

At this moment, network and bandwidth providers are at the heart of global megatrends such as IoT and the extended internet-of-everything. Radically increasing demands force innovation in the network landscape to be able to keep up with the development in the front-end market. An evolutionary change into a new system-of-systems places increasing demands on market players to collaborate, and opens up for new service layers as complexity is inevitable.

In managing time-varying demands on network capacity, inter-data center EaaS provides an option to efficiently allocate demands between data centers where capacity is available. This will allow for a more optimal infrastructure optimization as well as new pricing models.

Edge computing on the other hand soothes demand for bandwidth in an MTC environment as computation of sensor data is done locally on-device. As readily computed data is transferred regularly, variance of bandwidth demand decreases and the massive amounts of data grows manageable.

In a programmable world, virtual networks as a service can be matched to demands whenever need for data transportation, computation or communication increases. From a user point of view, this leads to an environment where costs can be held manageable using pre-determined rates of data transfer. Should the need arise, however, to increase accuracy - then it can be done all the way down to real-time analysis of raw-data. This, however, should be costly to maintain as demands on capacity increase aggressively.

As network capacity goes towards a utilities type of market, with the utility fully separated from the infrastructure, there is a risk of downwards price pressure as efficiency rises. In a utilities type-of market, basic needs are cheap and scale is king in order to achieve profits.

Nokia's part in this ecosystem lies in managing and optimizing virtual networks as a service, matching scaling and bandwidth. In other words, Nokia could introduce itself as a broker managing resources from those who have it to those who need it. This includes a matching/optimization problem between inter-data center EaaS and users to make sure users have optimized networks that meet specifications all the time. Facilitating these performance-on-demand networks, with needs triggered at the application level is a scalable opportunity for Nokia to pursue.

Key Points

1. With the proposed inter-data centers and EaaS models it is possible to utilize the full potential of the network within a teleoperations company and balance the network utilization between different teleoperations companies where Nokia can act as a broker.

2. With the amount of IoT devices exploding in the near future due technological breakthroughs e.g. power over WiFi, taking EaaS-model in use and exploiting mobile edge computing enables more flexible use of network.

3. These advances in telco technology open up new opportunities to introduce dynamic pricing models that can be used to grow Nokia's profits.

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