The role of E2E measurements in enhancement of transport resource utilization in mobile networks

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Abstract— **The design of mobile networks is witnessing a fundamental shift from being connection-centric to being content-centric. Mobile internet has transformed life and work, as a foundation for digital migration of humankind. These include HD video, virtual reality, augmented reality, driverless cars, real-time industrial control, Internet of Things as basic mobile services. In next years, most pressing issues for MSPs will be maximizing the value of mobile networks and enabling future service innovation. In this paper is given the way how effectively utilize existing resources for increasing content distribution and evolve mobile networks architecture, including E2E measurement model for transport part of 3G mobile network**.

Key words- E2E; Content; Internet; ICT; LTE; MSP and Service

I. INTRODUCTION

Throughout the evolution of mobile networks, the significance has always been on improving the communication capabilities such as peak data rate, minimum delay, and spectrum efficiency. Advances in modulation, channel equalization, and multiple access technologies facilitate the early generation mobile networks, whereas advances in channel coding, multiple-input multiple-output (MIMO), and orthogonal frequency-division multiple access (OFDMA) were the basic improvements of the third generation (3G) and 4G systems. In transport part new deployments provides evolution to all- IP with increase in scalability and efficiency. Network part must include End to End (E2E) capabilities as essential for supporting legacy and IP networks (support converged services). Service part has to deliver all services at a competitive price with profitable margins, including high quality and personalized approach. All resources need to be used more intelligently and efficiently, primarily according to the demands of the service and user. Mobile Service Providers (MSP) running different kinds of access, core, transport and service technologies and user experience to a considerable effort in applying their service and business requirements to the network and element management systems of different domain, [1].

MSPs are facing with the crucial changes in the dynamics of the market: constantly increasing amount of mobile devices and applications that are being released almost daily, the explosion of overall traffic demand and changes in customer behavior and expectations. The content - centric nature of mobile internet usage has turned the mobile network into a medium to connect people with content, highlighting ineffectiveness of the current connection-centric communication model (e.g. difficulties in dynamic content-to-location binding, mobility management, multicast, multi-homing, etc.). The constant increase in data traffic is also forcing MSPs to invest in their infrastructure capacity in all segments of the networks, from the core to the access and transport. Ensuring multiple network technologies increases operational and engineering complexity, reinforcing the need for new ways to evaluate quality.

To deliver a superior experience to users, mobile networks need a new technology approach. New system approach development strategy seeks to build fully open Information and Communications Technology **(**ICT) architecture to enable an industry shift from user experience to value creation across the *industry*. The permanent and fast evolution of technologies as well as user requirements drives revisiting new architecture and network reconstruction. In contrast to traditional management approach, new deployments require to include management as part of the functionality of a managed object. The process of a shift from hardware-centric to software-controlled, service-focused networks is in a progress. Basic principal is to move from simple connectivity to an E2E concept. That means realizing efficient data delivery without capacity over-dimensioning demands, in transport part of mobile network, for a flexible and adaptive traffic control, reducing congestion phenomena via effective statistical service multiplexing and by natively employing in-network caches.

II. TEHNICAL PERSPECTIVE OF FUTURE CONTENT DELIVERY NETWORKS

With the increase in traffic, content and applications, connectivity has become part of our work and life. From technology perspective competing standards requires much more complex networks scenario. The future network infrastructure have to support complete redesign of services and service capabilities, architectures, functions, access as

well as connection security. The important challenges that must be addressed by 5G networks is higher capacity, lower E2E latency, massive device connectivity, reduced capital and operation cost and consistent Quality of experience (QoE) provisioning. The pervasive and exponentially increasing data traffic presents imminent challenges to all aspects of wireless system design, such as spectrum efficiency, computing capabilities, and fronthaul/backhaul link capacity. Moreover, the technological advances proposed for beyond 4G and 5G mobile networks still mostly focus on capacity increase, which is fundamentally constrained by the limited radio spectrum resources as well as the investment efficiency for MSPs, and therefore will always lag behind the growth rate of mobile traffic. It can be encompass that the logjam in mobile networks cannot be addressed by upgrade connection capability alone, but instead must be tackled by fundamentally addressing the underlying ineffectiveness of the current communication architecture for massive content delivery, Table 1.

TABLE 1. FUTURE MODEL FOR MOBILE NETWORKS.

Requirements	Advanced approach
Heterogeneous network integration/ different network interfaces	Open control interfaces IP based NEs Big data model for resource allocation
E2E solution	Network intelligence and awareness to improve QoS, support services with network demand
Capacity	Bandwidth on demand, High spectrum utilization Latency and massive connectivity
Content	OTT cooperation framework Content delivery architecture
Business transformation	Faster adaption of new services, Faster integration of new services, Advanced CEM approach

Unlike the communication resource, which is fundamentally limited by the bandwidth and power, the computing and caching (i.e., memory) resources are abundant, economical, and sustainable. Various attempts have been made to accommodate expanding mobile services through the use of sustainable non-communication resources. For example, to deliver multimedia contents (which constitute most of mobile traffic), proactive pushing through data caching has been proposed at both base stations and mobile terminals. In addition to use caching to provide "individualized" services to mobile users, savings in communication resources can also achieved through computing, in which contents intended for different mobile users are logically processed through coded multicasting or similar techniques, [2].

More end users are using multiple devices with different capabilities to access a mix of best effort services (e.g., instant messaging and email) and services with quality of experience (QoE) expectations (e.g., voice and video streaming). Over-the-top (OTT) players provide services and apps, some of which compete directly with core operator services (e.g., voice, SMS, and MMS). Connectivity is increasingly evaluated by end users in terms of how well their apps work as expected, regardless of time or location (in a crowd or on a highway), and they tend to be unforgiving toward the mobile operator when these expectations are not met. Moreover, the battery life of devices and a seamless experience across multiple devices (or a device ecosystem) users.

The Internet of Things (IoT), which add "anything" as an additional dimension to connectivity (in addition to anywhere and anytime), is also becoming a reality. Smart wearable devices (e.g., bracelets, watches, glasses), smart home appliances (e.g., televisions, fridges, thermostats), sensors, autonomous cars, and cognitive mobile objects (e.g., robots, drones) promise a hyperconnected smart world that could usher in many interesting opportunities in many sectors of life such as healthcare, agriculture, transportation, manufacturing, logistics, safety, education, and many more. Even though operators currently rely on existing networks (especially widely deployed 2G/3G networks and fixed line networks) to support current IoT needs, many of the envisaged applications impose requirements, such as, very low latency and high reliability, that are not easily supported by current networks.

To cope with such evolving demands, operators are continuously investing to enhance network capability and optimize its usage. Operators are deploying more localized capacity, in the form of small cells. With the increasing complexity and associated costs, several concepts and technologies that have proved useful to the information technology (IT) sector are becoming relevant to cellular networks as well. For instance, an industry specification group (ISG) set up under the auspices of the European Telecommunications Standards Institute (ETSI ISG NFV) is currently working to define the requirements and architecture for the virtualization of network functions and address identified technical challenges, [3].

Mobile transport networks will play a vital role in future 5G and beyond networks. In particular, access transport networks connecting radio access with core networks are of critical importance. They will be required to support massive connectivity, super high data rates, and real-time services in a ubiquitous environment. To attain these targets, transport networks should be constructed on the basis of a variety of technologies and methods, depending on application scenarios, geographic areas, and deployment models: analog radio-over-fiber transmission, intermediate-frequency- over-fiber technology, radio-on-radio transmission, and the convergence of fiber and millimeter-wave systems that can facilitate building such effective transport networks in many use cases, [4].

III. ADVANCED E2E MASURMENTS FOR CONTENT DELIVERY MOBILE NETWORKS

The recent proliferation of smart mobile devices (smartphones, large-screen pads, tablets, etc.) and multimedia services (video on demand, live broadcast, social networks,

etc.) are accelerating the growth of video traffic on the Internet and users' expectation of retrieving contents with freedom of movement.

The mobile industry is in the midst of a major paradigm shift. Customers are demanding voice services less and data services more, and the transition appears rapid. Mobile operators around the world are investing heavily in their networks to bring the latest technologies to their customers. Big data is a new paradigm that that encompasses the principles of data in the new business scenario, [5]. For MSPs, the replacement of existing networking equipment and the introduction of a new foundation for traffic and network management will require comprehensive changes in management processes, practices, and organization, and hence major changes in the training and preparation of personnel. A completely new set of skills from the engineers that design and operate networks is required, personnel with the training that specifically consist converged IT and communication engineering in alongside with enabling technologies such as softwarization, virtualization, and cloud/edge/fog computing.

The social and economic value of data is mainly reaped at three stages: first, when data is defined and collected, second information is transformed into knowledge and when they are used for decision-making (taking action). The knowledge is accumulated over time by an individual or tools through data analytics. Data processing, management, and interpretation for awareness and understanding have been considered as fundamental processes for obtaining knowledge. Furthermore, the expectation process for actions should be additionally considered before decision making. As shown in Figure 1, data as a fundamental corporate MSPs asset should be considered throughout the whole process from data collection to decision-making for reliable services and applications delivery.

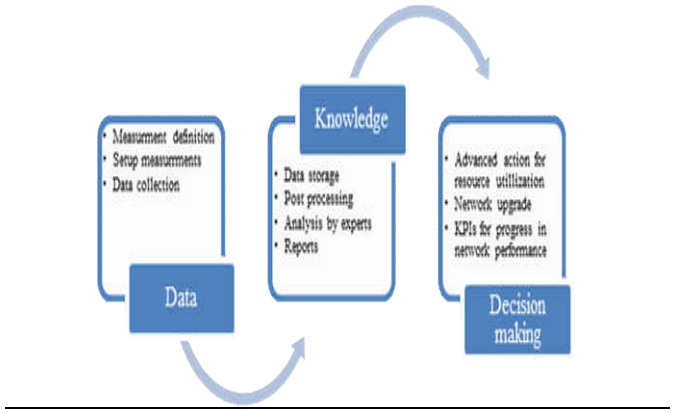

Figure 1. Turning data into knowledge.

Value of data is tied to its ultimate use, to MSPs that aggregate data in unique way and provide valuable analytics for decision making. Analytic tools can improve overall performance and create new opportunities. Most profoundly, decision making no longer have to be made on *gut instinct*; it can be based on evidence, experiments, and more accurate forecasts. Data and analytics can enable faster and more evidence based decision making.

Modern networks (especially LTE and future 5G networks) produce large amount of operation and management (O&M) data, which contain information for self-healing functions that MSPs need. To maintain a certain quality of service, self – healing system must complete tasks in a reasonable time. Self – healing system aims to automate troubleshooting, which is one of the most important O&M tasks. The amount of available data is often too big and unstructured to be treated with traditional statistic methods to achieve the results and the speed to cater for the needs of the market, so new techniques must be used. Big data is the new paradigm that encompasses the principles and techniques for making sense of data in this new scenario, [6].

IV. ADVANCED E2E MEASURMENTS IN TRANSPORT PART OF MOBILE NETWORKS

Current mobile networks generate massive amounts of monitoring data consisting of observations on network faults, configuration, accounting, performance, and security. Due to the ever increasing degree of complexity of networks, coupled with specific constraints (legal, regulatory, increasing number of network elements (NEs)), the traditional reactive management approaches are increasingly stretched beyond their capabilities. An E2E management paradigm is required that takes a proactive rather than reactive approach to network *improvements*. Following growth of users and devices, the number of NEs to manage will increase significantly. Also, as heterogeneous networks are becoming a reality with the deployment of micro-, femto-, and picocells, the complexity of the O&M tasks scales up accordingly. To maintain such complex mobile networks current O&M approaches need to be extended in order to provide efficient and high-quality services to end users. This mostly impacts operating costs for MSPs as today's approaches for monitoring rapidly expanding user and device volumes will require a significant increase in management personnel, which, based on current approaches, is economically unsustainable, [7].

E2E performance of the connectivity between mobile base stations and first core network element (i.e. BSC, RNC, GW…) is important for the E2E performance of the voice or data calls. In the past, the E1/T1 quality has been quite stable and either "on" or "off". This is different for packet-based mobile backhaul network (MBH) where the performance of the connection is not constant. Especially the delay is varying due to load situation in this case. A proper monitoring of the performance is helpful to identify bottlenecks in the network and to initiate proactive optimizations. In case of problems, the troubleshooting can be improved by considering performance-monitoring data. Based on model, turning data into knowledge, E2E measurements for 3G networks is given in Figure 2.

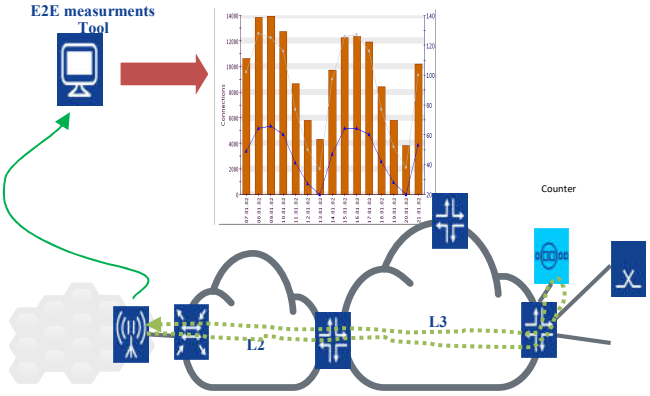

Figure 2. TWAMP model for E2E performance measurments.

Model for E2E performance measurments is given as TWAMP (Two Way Active Measurement Protocol-RFC 5357) measurments for voice and data, [8]. TWAMP measurement has been made for voice and data, using parameters as given in Table 2.

TABLE 2. TWAMP MEASUREMENT SETUP.

TWAMP measurement setup		
Voice	***Data***	***KPIs***
Simulate 3G voice traffic (DSCP, size, Tx-Interval)	Simulate 3G data traffic (DSCP, size, Tx-Interval)	Delay: 20 ms (one-way)
Measure continuously Delay and Packet Lossbetween NodeB and RNC on Iub Interface	Measure continuously Delay and Packet Loss between NodeB and RNC on Iub Interface	Jitter: +/-10 ms (one way)
Analyse data, check quality of MBH network	Analyse data, check quality of MBH network	Packet Loss: Voice 10^{-4} (= 0.01%) (one-way) Hi Speed Data 10^{-7} (= 0.00001%) (one-way

To better understand the meaning of the *collected* data, *experts* often use statistical techniques to simplify the representation of the collected variables. For instance, to detect degradations on key performance indicators (KPIs), thresholding is often used, that is, the value is considered degraded if it is above or below a certain threshold. Threshholding is especially important in the detection stage, but it is also used to discretize the value of KPIs, classifying them as either good or bad values. Transport KPIs should be below values as given in Table 2, (KPIs shall be met even under expected maximum traffic load). TWAMP traffic simulation for 3G data is given in Figure 3. (Iub Interface - between NodeB and RNC).

Target of this approach is to conduct analysis of the MBH in order to reconsider network performance, define KPIs and to identify and resolve packet loss, delay and delay variation problems in the mobile backhaul network. Analysis is focused on Ethernet and IP transmission domain.

The MBH Analysis service improves the MBH performance and finally results in better radio KPIs and better end user experience.

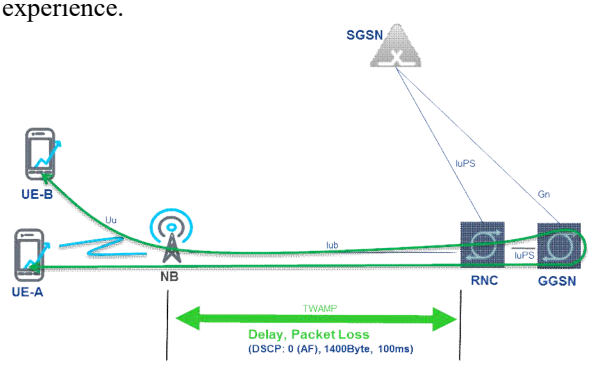

Figure 3. TWAMP Traffic simulation - 3G – Data

3G TWAMP statistics is used for monitoring of transport quality. NodeB allows activating up to 16 sessions with different DSCP and Packet Size settings. Still many MSPs do not have a proper monitoring solution in place to supervise the E2E mobile backhaul performance. The benefit of the E2E MBH performance analysis service is that the performance of the existing backhaul network is analyzed without the need to deploy any or only a very limited number of additional probes. Real-time visibility of traffic has potential to overcome the gaps in conventional testing standards that are only now emerging, as MSPs prepare to offer delay–sensitive applications.

User traffic can vary dramatically either at specific sites, regional area or across the network, reflecting responses to specific event. In network planning and optimization, these fluctuations must be constantly monitoring to keep pace with change use patterns. MSPs today typically dimension the network and apply traffic management and policy control to cope with data derived from traffic patterns in their network. In B&H, without 4G license, content delivery is possible only in 3G networks. MSPs in B&H are in quite unique position, since delivery of content services is possible only in 3G networks. Increasing user demands and competitive market creates a need to improve offered services as well as the degree of utilization of existing resources. E2E model ensure which specific hop/NE is causing degradation. MSPs need to detect whether is a capacity or a configuration issue, what specific capacity and configuration issue and how much they need to adjust it. With rapidly increasing multimedia traffic levels and demands for bandwidth, the number of possible MBH failure points and bottlenecks requires new levels of performance visibility. E2E model helps MSPs optimize network capacity and improve MBH performance.

V. CONCLUSION

Telecommunication networks, as large and complex systems, are very difficult and expensive for management. Predicting, preventing, mitigating, and proactively fixing problems are key strategies in reducing operational costs. End-to-End model based on per-usage metrics can give valuable

insights for positioning MSPs as innovators of services. Model for 3G environment is given as a tool for improving transport network resources efficiency. Data and analytics have great potential to create value. MSPs that are able to use these capabilities effectively will be able to create significant new value and differentiate themselves at the market.

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