Network Monitoring Challenges in the Evolved Packet Core

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Abstract: The move towards broadband converged networks and applications is increasing the need for advanced network monitoring. As the EPC will completely overhaul the classic GPRS architecture by replacing it with a much flatter all-IP network; it will become a single converged core handling all applications including the existing telephony services. In this context, application performance monitoring will be essential in order to measure the user experience and to get more insight into the traffic trends and applications usage. In this paper, we will discuss the challenges facing network monitoring in EPC and provide recommendations in this regard.

Keywords: Monitoring, performance, EPC, LTE, SON, DPI, KPI, QoS, QoE

1. Introduction

This paper considers network monitoring challenges in the next generation of mobile networks. The move toward broadband converged networks and applications will tremendously increase the demands on the infrastructure. Wide-scale of applications including mobile services (e.g. telephony, SMS) and Internet based heavy-traffic applications (e.g. video streaming, file downloads, etc.) will be running on the same network. At the same time, with the proliferation of multimedia enabled devices (e.g. smart phones, tablets), end-users will be expecting a service quality in par with wired Internet. This raises a critical question: how can network operators ensure that they deliver quality services? One way is to overprovision, but a more viable way is to constantly monitor the performance of the network along with the delivered applications. The focus therefore needs to shift from the transmission and signalling plane to the user plane and applications, requiring a deep view and ability to follow how the applications are performing and obtain the necessary insight on the quality that each individual subscriber experiences. This accentuates the need for Deep Packet Inspection (DPI) technology in network monitoring.

On the other hand, Self Organized Networks (SON) [1] introduced as part of the LTE consists a key driver for increasing the network performance and improving the efficiency of operation and maintenance (O&M). However, the risk of un-tuned SON functions is severe. In a multi-vendor environment, monitoring the impact of SON on the network becomes essential to ensure it operates as expected.

This paper presents initial investigations on network monitoring in the context of MEVICO [2] research project. MEVICO is a Celtic Call7 project that investigates

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aspects of the 3GPP LTE-mobile broadband network towards its evolution in the mid-term in 2011-2014 and beyond. The goal is to contribute to the technical drive and leadership of the Evolved Packet Core (EPC) [3] network of the 3GPP, and thus support the European industry to maintain and extend its strong technical and market position in the mobile networks market. The project follows an end-to-end (E2E) system approach towards the evolution of the EPC. The technical research of the project covers relevant topics in the areas of network architecture, mobility and routing, packet transport, traffic management and engineering, network monitoring and management, and techno-economic aspects. The project will include both conceptual research and demo/trial system implementations.

The rest of the paper is organized as follows: section 2. discusses performance monitoring topics and a set of advanced capabilities DPI brings to monitoring systems. Section 3. presents a methodology and metrics for monitoring the impact of SON functions using non-intrusive techniques. Section 4. presents the high level network monitoring architecture before drawing a conclusion and an outlook of future plans in section 5.

2. Performance monitoring

QoS performance monitoring is based on the analysis of QoS performance indicators in one or different points in the network. It is required for tracking and comparing the network behaviour against a quality baseline in order to detect possible degradations. It provides an input for fine-tuning the network resources in order to optimize the QoS.

Performance monitoring in EPC networks is a challenging task due to many factors. One of these is that, in flat all-IP architecture, high value services such as telephony compete for network resources (i.e. bandwidth) with the rest of Internet based services. There is a need for high achievable bit rates in a more diversified application mix. In this context, performance monitoring should provide the ability to:

- Monitor the performance and the QoS parameters on a per application basis (e.g. Skype, YouTube) and on per-class of application basis (e.g. P2P, internet video).
- Monitor the experience of individual users.

This raises the need for a means to identify the type and the class of used applications. In the following subsections we will discuss these topics in more detail.

2.1 Application identification and classification

In network monitoring, we refer to application classification as the process of identifying the type or the class of an application. This is necessary in order to monitor performance on a per-application basis in a context where the operator provides a limited number of services (but with high added value) compared to the Internet based services. Unfortunately, port based application identification is not accurate since a high number of applications use non standard port numbers. Thus, advanced techniques such as Deep Packet Inspection and statistical methods are required in monitoring systems. It is a challenging task to classify applications accurately and no single method can provide satisfactory classification of all applications. Therefore, combining different complementary techniques is often necessary. Moreover, the application mix, with its characteristic signatures and traffic patterns, steadily changes. This makes it also necessary to constantly adapt identification methods to new or modified formats. Another
essential factor in application classification is to reduce the number of false positives and false negatives in order to achieve the necessary precision for acceptable usability.

2.2 Application and subscriber performance monitoring

The performance of a mobile provider’s services directly influences the subscriber’s satisfaction level, which in return will have a significant impact on the operators’ future revenues and churn rate. Services will become more complex due to network convergence and consolidation. Handovers across different radio access technologies (outside the actual EPC) might impact the application performance as perceived by the end user. These users demand more quality and, at the same time, mobile applications consume more bandwidth. Accordingly, it is critical to ensure that the delivered service quality is respecting user expectations. Application and subscriber performance monitoring is therefore essential in this context. This consists in measuring KPIs and metrics relative to each application and subscriber. Application specific metrics are necessary in order to assess the performance of the network with respect to application requirements. Subscriber based performance monitoring consists in measuring the quality metrics of the application sessions as perceived by the subscribers. Application and subscriber powered performance monitoring system will thus allow operators to follow application performance and to determine the quality experienced by subscribers. For this end, it is essential to:

- Widen the monitoring and measurement focus from the transmission and signalling plane to the user plane and applications. This requires a deep view on the control and data traffic and introduces the need to integrate DPI technology into the measurement probes.

- Provide multi-granularity reporting for both the signalling and the user plane. It should be possible to look at the network’s global KPIs, such as the attach procedures, paging delays, context activations, etc.; and then drill down to a detailed view of the control plane and applications whenever more sophisticated troubleshooting is needed. Service and subscriber-based key quality indicators (KQI), combined with the ability to see the services’ and customer’s QoS with high accuracy, will help answer some of the mobile operators’ challenges by providing them with comprehensive data allowing the analysis of degradations or errors and the determination of appropriate actions (e.g. determination of legal responsibilities).

2.3 Application based user experience estimation

With the proliferation of smart phones and the widespread usage of social networks and multimedia services, the users have transcended requirements on connectivity and quality. For service providers and network operators, it is very important to determine, with reasonable accuracy, the mean opinion score (MOS) in order to measure user satisfaction. This depends highly on the application class. In many cases, especially when Internet services/applications are considered, providing basic network metrics and some application specific metrics is sufficient. However, this might not be the case for high value added applications and services like telephony, video, etc. Monitoring systems have a big role to play in this respect by integrating methodologies and tools that objectively reflect the user’s quality of experience.

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2.4 Deep Packet Inspection (DPI) in network monitoring

DPI is a networking technology involving the process of examining the header and, potentially, non-header content (i.e. payload) of a packet by a system that is not located at the communication endpoints.

DPI offers a wide set of capabilities ranging from microscopic packet and flow level analysis of user plane sessions to a more global aggregated application level traffic analysis. With these capabilities, DPI fosters application and subscriber performance monitoring where it will play the role of traffic information provider. Therefore, in order to improve the understanding of the dynamics within the network, we recommend powering monitoring probes with DPI functions that provide the following capabilities:

- Application type identification and classification (e.g. Skype/VoIP).
- Flow metrics and protocol attributes decoding consisting in extracting traffic information relative to the same data flow of an application connection. This includes i) quality metrics such as packet loss, jitter, RTT, response time, MOS, KQI, etc.; and, ii) packet decoding to retrieve traffic metadata and content such as the IP address, the TCP sequence number, the HTTP method, the RTP audio codec, terminal type, etc.
- Subscriber based traffic inspection. The application identification/classification combined with flow metrics makes subscriber based monitoring possible. It allows detecting, for instance, the applications used by the subscribers, the relevant QoS metrics and KQI of the subscribers.
- Application traffic events and statistics. In addition to the microscopic view of traffic flows, DPI should provide also more application aggregated traffic information. This should include the identification of the most common applications in the network, the measurement of quality metrics (e.g. throughput, latency, response time, packet loss), identification of popular content (e.g. YouTube videos, file downloads), and subscriber analysis to determine KPI/KQI of delivered services (e.g. Video on Demand).

In the MEVICO project, DPI will be involved particularly in the following use cases:

- **Customer Mobile Data Experience** (CMDE) that involves DPI capabilities such as: application classification, traffic metrics extraction, QoS requirement mapping and identification of popular content. To be able to do this, the monitored interfaces should include S1-U for GTP tunnelled user data and S6a for authentication data. Customer identification (for reporting purposes) will be based on IMSI and IP addresses acquired from the S6a interface. DPI analysis and data aggregation will happen as early as possible in the network probe in order to manage heavy traffic loads that the user plane generates. This DPI analysis will provide IP flow and application level information per user, which will be translated and mapped to KPIs/KQIs.

- **Home Agent initiated flow binding** intends to offload traffic flows from 3G/4G networks to Wi-Fi in high loaded mobile network segments. The network initiates flow binding based on resource availability and service policies (SLAs).
traffic management activity will involve the following DPI capabilities: application class identification, QoS differentiation and measurements. DPI will provide the necessary fine-grained measurements for the flow binding algorithm.

3. Monitoring of Self Organized Networks (SON) operation

SON functionalities are important components in LTE network management. SON is a set of functions that intends to minimise operational costs by introducing self configuration and self optimisation mechanisms in a multi vendor environment. Although the network measurements required by SON functionalities are implemented internally in the network elements (e.g. eNB), passive monitoring of SON operation is essential in order to: i) measure the network impact of the SON functions; and, ii) test and validate their behaviour in a multi-vendor environment. Monitoring SON using passive non-intrusive methods is a challenging task due to a number of factors including:

- The passive nature of SON monitoring requires observing the interactions between involved nodes or elements. All internal counters and statistics are simply invisible from a monitoring point of view. Accordingly, finding the right measurement points which depend on the network and SON solution architecture is crucial.

- Most of the SON use cases are still in an early standardization phase and many points are left for the equipment vendors for further specification. However, the interactions on standard interfaces (S1 and X2) are defined; this makes equipment independent SON monitoring possible.

- The definition of KPIs for assessing the impact of SON on the network using passive monitoring is not straightforward requiring thus innovative research work.

In order to define KPIs for SON monitoring, we applied the following methodology and guidelines:

- First, we conducted a thorough analysis of existing SON use cases [1] [4] to identify their objectives, expected results, and the way they impact radio parameters.

- Next, we classified the interactions and measures used by the SON use case into observable and non-observable. Only observable interactions can be monitored.

- Finally, for every observable SON function, we defined:
  - The different interaction scenarios (e.g. message exchanges over the X2 interface),
  - How the interactions map to the objectives and expected results of the function,
  - A number of appropriate KPIs to measure the impact of the function on the network. For every defined KPI, we highlighted the motivation for measuring it, how it can be measured, where it can be measured, and when the measurements need to be done. In addition, we also analysed at what point in the network life cycle a KPI is more suitable.

These guidelines were applied on four different SON use cases. In the next section, we shortly present the approach applied to the Mobility Load Balancing use case; further details can be found in [5].
3.1 Monitoring Mobility Load Balancing (MLB) use case

MLB [1] aims to optimize cell reselection/handover parameters in order to cope with the unequal traffic load and to minimize the number of handovers and redirections needed to achieve load balancing. MLB is expected to improve system capacity and load distribution, and minimize human intervention in management and optimization tasks. For MLB, an eNB monitors the load in its controlled cells and exchanges load information with neighbouring eNBs in order to decide on the appropriate candidate cell for the load balancing. In intra-LTE MLB, load information is exchanged on the X2 interface using ‘Resource Status Reporting’ procedures and the output of the algorithm is a ‘Handover Trigger Threshold’ parameter that can be negotiated over the X2 interface by means of ‘Mobility Settings Change’ procedures. Based on these observable exchanges, the following KPIs were defined for monitoring the MLB function.

**Load balance indicator of the node:** In an ideal situation, the load between neighbouring cells should be balanced, but this is often not the case in practice. Based on the resource status reports exchanged between neighbouring eNBs, it is possible to calculate the load disparity (i.e. the balance indicator) among the different cells (for instance, the weighted fairness index is a possible candidate). This indicator can be measured by inspecting ‘Resource Status Reporting’ procedures exchanged periodically over the X2 interface and the ‘Mobility Settings Change’ procedures holding the ‘HO Trigger Threshold’ parameter expected to balance the load. By comparing the variation of this index, the impact on the network can be deduced. This indicator is suitable for both assurance and maintenance phases.

**Handover (HO) ping-pong rate:** This indicator is motivated by the fact that the MLB algorithm should converge by nature (fundamental property for stable control algorithms). In other words, assume we have two eNBs: eNB-A, that is highly loaded, and eNB-B, that is less loaded. The MLB function should not produce a load balancing ping-pong between the nodes; in other words, ping-pong HO occurrences between the cells should not be detected. This indicator can be measured by inspecting the X2 interface for HO related control messages (e.g. Mobility Procedures) to detect occurrences of ping-pong HOs. By correlating the HO ping-pong to the ‘Mobility Settings Change’ procedures, the variation of the ratio before and after the application of MLB reflects its impact. This index targets mainly the MLB algorithm itself. It is most suitable for evaluation in a controlled environment (R&D phase) where access to all interfaces is possible (including user side emulation and testing) or for on-field testing where the operator might like to measure the impact of MLB on the ground (e.g. during the roll-out phase).

**Variation of the QoS of the impacted users:** This indicator is motivated by the fact that MLB should not negatively impact user QoS. Therefore, the evaluation of the impact of MLB function can be measured through the variation of the user QoS prior and following the application of the function. The user QoS can ideally be measured on the terminal side (i.e. radio interface) or within the network on the S1-U interface. In both cases, the X2 interface should also be inspected in order to correlate the QoS variation with the MLB events (‘Mobility Settings Change’ procedures). This index is more suitable for evaluating MLB in a controlled environment (R&D phase) where access to all interfaces is possible (including user side emulation and testing) or for on-field testing as in the previous case.

**Human intervention rate:** This long term indicator is intended for measuring the
impact of MLB on the number of human interventions in network management and in the optimization of mobility parameters. This indicator is not observable using passive methods. However, it can be calculated by the operator based on the relevant events in the management system. It is suitable for both the assurance and maintenance phases.

4. Monitoring architecture

![Diagram of monitoring architecture](image)

Figure 1: Mapping between monitoring measurement points and network standard interfaces.

In an abstract view, a monitoring system is composed of a number of network probes, one or a multiple of correlation and analysis units, and a central monitoring system. Measurement units (probes) will collect data at different points of interest in the network in order to obtain comprehensive understanding of network and service behaviour. Correlation and analysis units will inspect collected data to calculate KPIs, KQIs and all other metrics of interest. With KQI information, network monitoring systems are capable of showing network quality information and service quality levels with one-glance views, enabling ease of use operator applications. As KPI information is often multi-level, several KPIs can be aggregated and processed to get network-wide KPIs. The central monitoring system will process collected data to provide service status information, SLA reporting and Business Intelligence (BI) information like historical and trending reports. Collected information and data can also be stored to databases for future analysis or to be made accessible to third party external systems. The selection of observation points is therefore critical in network monitoring. This selection process should take into account the monitoring needs (e.g. network monitoring, application performance monitoring, subscriber monitoring, user experience monitoring) to select
the EPC interfaces where measurement probes should be installed. In addition, the network deployed architecture imposes new constraints. The network monitoring architecture must be flexible and adaptable to the network architecture. In the MEVICO project, three different architectures are subject to study: central, distributed and flat architectures. These different network architecture variants will impact where physically the measurement points will be placed, what are the processing requirements of these measurement points and so on. However, the interfaces subject to inspection will not change. Accordingly, we have defined, in Figure 1, the network interfaces subject to inspection and measurement in the context of network monitoring. User and control planes on the S1, SGi, S5/S8 (if physically present) and S10 will be inspected for application and subscriber performance monitoring. On these interfaces, DPI will be performed to enrich data collection. SON monitoring, on the other hand, will consider S1-MME, S1-U and X2 interfaces. In controlled field or R&D testing, SON monitoring might need to consider the radio interface as well.

5. Conclusion

This paper presented the initial work performed in the context of the MEVICO project in the field of network monitoring. Two main network monitoring challenges have been identified. In the first, performance monitoring needs to shift its scope to the application and subscriber level. In this context, DPI provides advanced capabilities that can highly enrich measurements and indicators. In the second, passively monitoring SON operation is crucial, particularly in multi vendor environments, in order to assess its impact on the network. We have defined a methodology to analyse and determine the appropriate performance indicators that can reflect the impact of SON. So far this methodology has been applied on four different SON functions.

Our future work consists of extending the SON monitoring methodology to additional use cases. We will be working as well on validating SON monitoring on a real testbed. The performance monitoring as well as the DPI capabilities will be subject to evaluation and validation during the last phase of the project.

References


