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Broad Network Wide Statistics of TCP Indicator Measurements to Reassume the Status of the Wireless 3G Network Monitoring

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Abstract

Numerous services of practical concern stem from the potentiality to monitor stored packet-level traces in a Third Generation (3G) network. Unexpected traffic load in the Internet is a familiar fact or principle. Any network that has been engineered without taking its presence into account might experience problem during periods of massive exposure during grand-scale monitoring. This study is based on seven days of packet traces collected in the UMTS core network. The approach exploits statistics of estimated TCP performance parameters (i.e. RTT, re-transmissions) in order to build a set of indicators. Among them, there are likelihood to presume locate systems of network quandaries (i.e. persistent shortage of retention, or apparatus miss-functioning) in the core and radio fragments use without straight access to the appliances. This system yields strong exercise convenient, given the charges and perplexity of using network equipments, especially in the wireless Radio Access Network (RAN). At the same time, it pictures precise quandaries (i.e. the need to dynamically endemic the traffic sources (Mobile Stations)) and theoretical difficulties (i.e. recognizing congested cells as of Routing Area level TCP measurements). This application is particularly important for operational UMTS network nowadays, since the traffic volumes and composition are still under evolution. The authors hit-off on this work-in-progress aimed at accomplishing such apparatus on top of a highly developed monitoring network system now extended in an operational network.

Keywords : GSM, UMTS, 3G, Passive network, RAN, TCP, CN

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INTRODUCTION

Wireless systems of wide area public network are now moving towards Forth Generation (4G) and Fifth Generation (5G) mobile systems, drawing to corroborate packet switched data applications. The Universal Mobile Telecommunication System (UMTS) has been espoused in Asia, evolved by 3G Partnership Project (3GPP) as an evolution of Global System for Mobile Communication (GSM). Two main sections are included in 3G network, (i) Radio Access Network (RAN) and (ii) Packet Switched Core Network (PS-CN) where the interface between Radio Network Control (RNC) and PS-CN are called IuPS where Iu interface carries traffic (like as voice and data) as well as control information, which is developed on the basis of Internet Protocol (IP). Based on WCDMA having been developed UMTS RAN (UTRAN), several operators maintain a parallel General Packet Radio Services (GPRS) RAN developed from the inheritance of GSM system. This structure is sketched in Figure 01. A number of UMTS networks became functional since 2003 while first deployments of GPRS date back to 2000. Since then, the reputation of developing 3G networks and services have extended the coverage of Internet access to the geographical territory and become key elements of the global Internet in America and Europe. However, the 3G ambient is yet to be developed properly in Asian countries like Bangladesh, at least along the following parameters:

_ traffic capacities and subscriber population

_ terminal capabilities and relative penetration of the various terminal genres (laptops with 3G card, handsets, and so forth.)

_ applications portfolio and duties offered by the agents.

Technological improvements are still in the list of items of many operators like High Speed Downlink Packet Access (HSDPA) in the UMTS RAN, Enhanced Data Rate for Global Evolution (EDGE) in the GPRS RAN and IP Multimedia Subsystem (IMS) in the CN [1]. All these features collectively build it possible for changes in the worldwide traffic that can happen at the macroscopic level (network-wide) and in a comparatively short time frame. Hence, the aptitude to precisely and comprehensively monitor the network standing and to early identify drifts in efficiency and/or local problems is a fundamental support of the network function and optimization procedure. Monitoring system a wide-area network is not a simple job. First, the number of ingredients is big and they are extended geographically. Secondly, for most matter-of-fact reasons, it is essential to use configuration parameters (i.e. provisioned bandwidth), logs and counters from ample network components, with dissimilar software and from dissimilar vendors, and considerable prices, complications and difficulties detected in practice where it approaches to extraction, congregating and correlation of like heterogeneous data (i.e installing and maintaining a monitoring infrastructure with straight access to the network ingredients of the manufacture network is extremely expensive). Furthermore, the granularity and the quality of the data accessible from the appliances (i.e built-in counters) are often poor and/or insufficient for in-depth study of the network state.

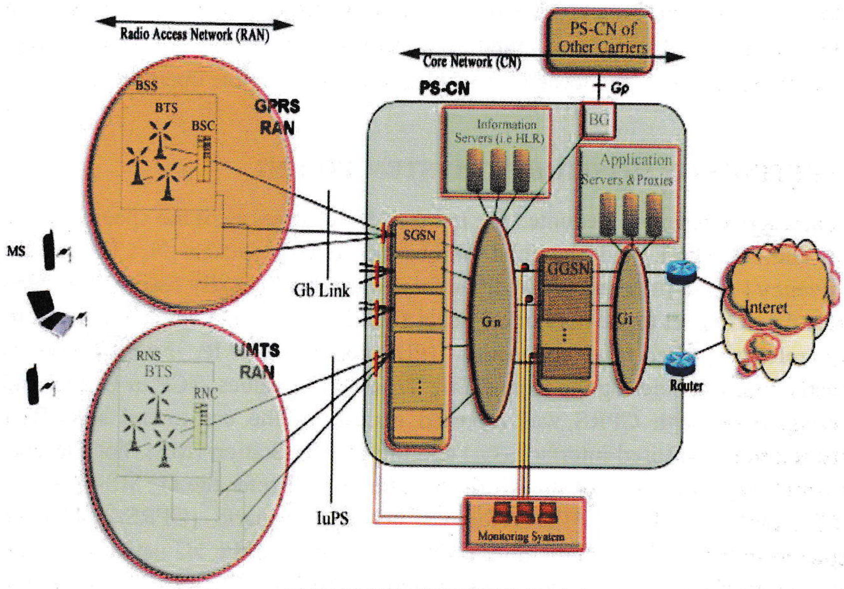

Figure 01: Formation of 3G Network System

In this research it is exploring the feasibility of monitoring a production 3G network completely by passive sniffing packets on few key Core Network (CN) links exclusive of direct use to the appliances. This approach yields a number of practical benefits and opens fresh further prospects for improving the manufacturing and operation of an actual network. For instance, the amalgamation of location data extracted from the signaling segments with indicators of Transfer Control Protocol (TCP) performance (i.e. Retransmissions Timeout (RTO) and Round Trip Times (RTTs) to monitor the actual performances of the entire RAN, and to spot the requirement for home radio re-optimization intervention, not including direct access to the RAN equipments. This approach is analogous in principle to passive network tomography. An additional value point of passive monitoring, while attached with trace storage, is the likelihood to execute post-mortem analysis of network problems. Practical to 3G, it consents for pioneering study instructions unexplored so far, like the evaluation of the possible impact of undesired traffic load (i.e. worm infections, Denial Of Service (DoS) assaults) onto the functionally complex 3G network infrastructure, or the analysis of signaling traffic to emerge buggy terminals or network miss-behavior on the control panel. Although such approaches are not new in the general sense, nevertheless, their application to the exact circumstance of 3G networks divulges new uncharted facets. In this contribution it tried to enlighten the prospects of fine-grain monitoring a 3G network system with a focus on the trouble of grand-scale packet-level performance monitoring. The authors report on the foremost technical concerns and the open points.

1. SETTINGS OF MONITORING SYSTEM FOR 3G

In each active terminal I counted the number of occurrences of the specific event (i.e. SRTO) n s i, and the total number of DATA packets N_i. The global frequency $\int_s$ is defined as $\frac{\sum_i n_{s,i}}{\sum n_i}$. IP addresses are dynamically assigned to MSs when they connect to the network (Packet Data Protocol-PDP context activation) and released when the connection (PDP-context i.e. IP, FrameRelay) is deactivated. Considering the Round Trip Time (RTT) values, TCP in UMTS and a comparison with GPRS was reported instead of the end-to-end semi-RTT between the monitored interface (G_n) and the Mobile Station (MS). For the sake of simplicity, in the rest of this work the authors will refer the G_n-MS-G_n semi-RTT simply as "RTT". The reference network scenario (GPRS/UMTS) is depicted in Figure 01. As any other right to use network, the 3G network system has a hierarchical like tree deployment status. The Base Stations (BSs) and the Mobile Stations (MSs) are geographically nation-wide distributed. Going up in the hierarchy fact that at first Base Station Controller (BSC)/ Radio Network Controller (RNC), afterwards Serving GPRS Support Node (SGSN), in the end Gateway GPRS Support Node (GGSN) the level of attentiveness increases, is involving progressively a smaller number of appliances and physical locations. In fact, the G_n interface is basically a wide-area IP network inter-connecting the different SGSN/GGSN sites and as such it embeds routers, subnets IP and so forth. In a typical network system there are comparatively few SGSNs and even smaller number GGSNs. Consequently it is probable to take a snapshot of the whole data traffic from local users on a minute number of G_n/G_i interface links. Nevertheless, for some services it is necessary to access the G_b/IuPS interface link near the SGSNs. Besides, monitoring every interface requires the acquirement system to be capable of parsing and understanding the full 3G protocol suite, for both the signaling as well as user plane. The development of a grand-level passive monitoring structure, including a parser for the entire PS-CN protocol stack, and its implementation in the activational network were implemented within the METAWIN project [2], enabling to passively monitor all CN borders interfaces (G_i, G_n, G_b, IuPS). Frames are taken with Data Acquisition and Generation (DAG) cards and documentation with GPS synchronized time-stamps and large-capacity storage system like Home Location Register (HLR), a central database that contains details of each phone subscriber at the accessible cost. For privacy, basics vestiges are anonymized by hashing all grounds linked to user distinctiveness at the 3G lower layers (MSISDN- the telephone number associated to each SIM, International Mobile Subscriber Identity (IMSI), etc.), at the same time as the user payload the TCP/IP layer is detached. As discussed, one key feature in several monitoring relevance is the capacity to refer every packet to the analogous MS and to its existing radio site (i.e. at higher granularity in a cell) which is so called Routing Area (RA). It is probable on the G_n interface to pass on packets to MS, but not to its site. Actually, when exchanging data traffic MS necessary to institute a logical link with the GGSN, the so called "PDP-context" is the 3G homologous of a dial-up connection in a modem-based ISPs where IP addresses are dynamically assigned at the PDP-context activation, which is maintained for the entire activity time (ranging from sub-second to few hours). The situation of PDP is analogous to a modem dial-up link in ISP networks. It is a significant entity in the 3G dynamics, since a number of purposes are executed on a per-PDP situation basis (i.e. the handing over of IP address, production of billing ticket) and significant parameters of attention (i.e. Access Point Name (APN), QoS parameters) can be sniffed barely throughout the PDP-context opening process. This monitoring system tracks these signaling segments and maintains situation for every active PDP-context. It is capable to pass on each incoming packet on G_n to the PDP-context of corresponding and, therefore, to the creating MS. A number level of localization is probable by sniffing on IuPS (for UMTS) and on G_b (for GPRS), with different systems for the two owing to diverse protocol stipulation. It is all the time potential to discriminate accurately the existing location of MS at the Routing Area level (a anthology of some contiguous cells), for both UMTS and GPRS, also for those MSs that are currently closed to the network but not concerned in active traffic exchange (i.e. Updates of Routing Area). The localization of finer-grain (i.e. per-cell) is probable in GPRS barely for active MSs. As a result, it is potential in GPRS to pass on data packets (in uplink and downlink) to the existing cell. In order to UMTS the localization of per-cell of data packets is not completed: as a MS shift into a new Routing Area (RA), barely the first visited cell is hit off to the SGSN and can be hence sniffed on IuPS interface. Following cell changes within the RA are not "seen" on IuPS and, therefore, are not well-informed by this monitoring system. This feature makes the job of revealing cell-level problems (i.e. congestion) more demanding in UMTS than GPRS because the cells within a RA are not independently and accurately apparent, therefore, requiring additional inference procedures. Lastly, based on the RA and/or local connection information, it is probable to associate the packets captured close to the SGSNs (on G_b/IuPS) to the present BSC/RNC, a basis for revealing problems or further divergences at the level of these appliances.

2. GRAND-LEVEL MONITORING PERFORMANCE IN 3G NEWORK SYSTEMS

Likewise to wired network system, TCP is the leading traffic element in the 3G network. In view of the fact that TCP is closed-loop controlled, its activities depend on the situation of the end-to-end path. For both the microscopic (per connection) and macroscopic levels (per aggregate) are accurate.

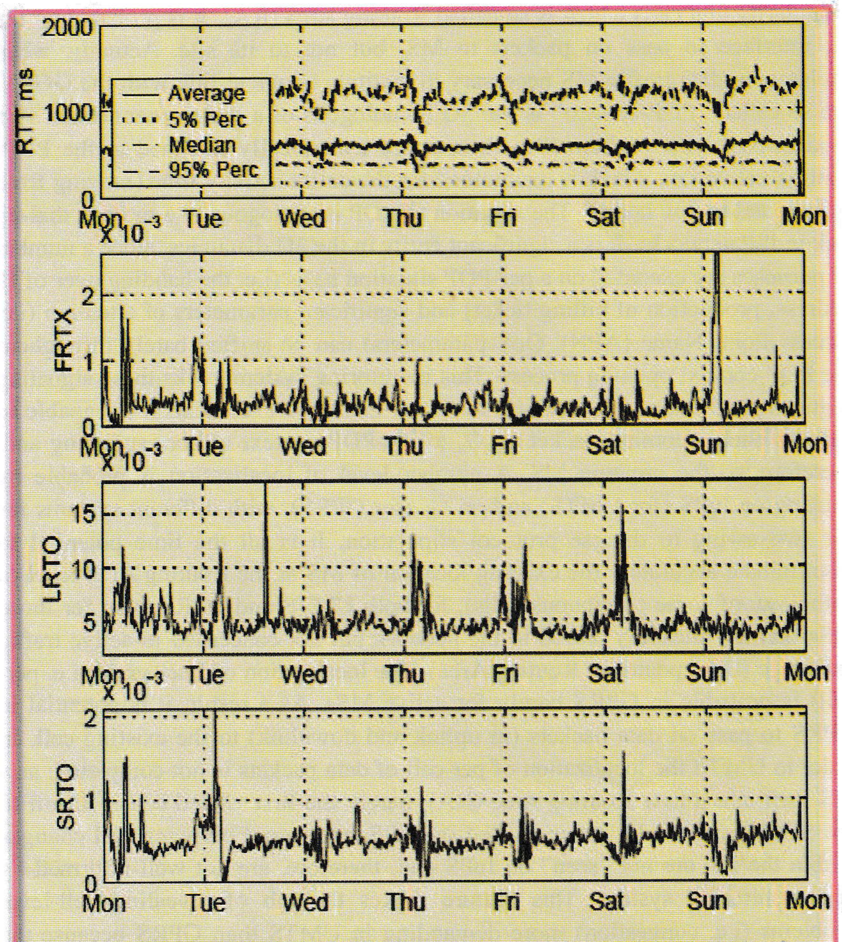

Figure 02: Measured TCP Indicators on UMTS (1 week, 15 min bins)

Tools have been developed to estimate several TCP performance indicators (i.e. RTT, RTO) by evaluating the behavior of entity links (micro level) as of passive traces (i.e. tcptrace) [3]. Ideas were also recommended to extract pointers of anomalies at the macro level [4]. Broad network statistics of TCP pointers presume the status of the complete network system: over long time-bins of average they can be exercised as synthetic worldwide Key Performance Indicators (KPI), cooperative for revealing macroscopic drifts in broad network contributions (i.e. owing to slow changes of the international traffic allocation) or for quantifying the real development upon hi-tech improves (i.e. HSPDA, EDGE). For instance, Figure 02 [5] reports, in UMTS for one week in October 2005, numerous TCP indicators deliberate the assessment with past measurements does not divulge any sensible performance move after one year in spite of the substantial increase in traffic volume. It plotted the measured values for each parameter in time bins of 15 minutes. The top sub graph shows the average and several percentiles (5%, 50%, 95%) of the RTT samples extracted in each time bin. The remaining sub graphs report the measured frequency of FRTX, LRTO and SRTO respectively. It appears that the RTT statistics display a large variability, with average values occasionally very large. However, a deeper look would reveal that most of the RTT spikes occur over night, when the traffic volume and the number of active terminals are very low. This suggested that such spikes might be the effect of few terminals generating a large volume of packets and hence RTT samples. In case that such packets are associated with large RTT values for some specific reason (i.e. poor local radio condition, intensive mobility, application-specific ACK delay), they introduce a bias in the whole RTT statistics. This is more likely when the network load, i.e., the number of terminals is low.

In view of the other parameters, it is evident that Fast-Retransmit Re-transmissions (FRTX, the re-transmission of a packet triggered by duplicate ACKs) and Spurious Retransmission Time-Outs (SRTO, the occurrence of a re-transmission due to RTO expiration caused by a large delay without packet loss) frequencies display periodic spikes before day 7, particularly at the peak hour. Among them, the SRTO seems to be the best indicator for this type of bottleneck. In fact, it can be seen that after the bottleneck removal, the SRTO frequency stays at a "physiological" level (below 0.1% in UMTS) that is highly stable: no large fluctuations are present, and there is no apparent dependency on the time-of-day and, therefore, on the network load. In other words, the "normal" value of SRTO frequency in UMTS is invariant to changes in the network load. For Loss-induced Retransmission Time-Outs (LRTO, a packet re-transmission triggered by the expiration of the TCP Retransmission Time-Out caused by packet loss), the occurrence of a re-transmission due to RTO expiration caused by a large delay, without packet loss, there are no evident differences in the behavior before and after day 7. However, similarly to the RTT, most of the spikes seen for FRTX and LRTO after the bottleneck removal are placed at off-peak hours, which again suggest the possibility of bias from a few top-outliers' terminals.

In connection with the RTT statistics, the filtering process had dramatic effect and almost completely canceled the fluctuations of the average- now firmly anchored to the level of 500ms – and of the lower percentiles. The RTT process, at least as estimated with the described above, is not a good indicator. The likely explication is that the RTT estimation process implemented in tcptrace only considers selected DATA-ACK pairs that do not hold any ambiguity in the RTT estimation. This method filters away "invalid DATA-ACK pairs," that typically emerge in the neighborhood of events like packet loss, retransmissions and time outs.

When joined with routing information, these indicators can be applied to deduce the attendance of performance degradation points far-away from the monitoring point. This method, a form of "network tomography", fits satisfactorily to the 3G Core Network owing to a quantity of key unusual characteristics like tree structure, regularity of paths, partition between servers (on the G_i side) and clients (the MS). This permits to monitor the definite value and the performances of 3G network at the packet level for the entire CN, and to confine irregularities. Besides, the grouping of these indicators with the per-MS position data removed from G_b/IuPS traces makes it potential to pass on performance indicators to exact radio areas (cells or RA), in order to build "performance maps" in time and space. As of there, one can apply comparatively easy apparatus for detecting regions of persistent or recurrent performance degradation, straight spotting difficult areas. Some degree of numerical deduction is necessary to overcome the lack of entire per-cell resolution in UMTS, where correct maps are obtainable barely at the RA stage. The more connection with "load maps" (i.e. number of active clients and/or transmitted volume per cell) would be useful for discriminating between probable reasons, for instance, troubled radio coverage against lack of radio capability, and then trigger local involvement (radio re-optimization). The worldwide statistics can be discriminatory by some MSs experiencing extremely poor transfer conditions. To shun false alarms, caution is necessary to discriminate situations whereas the poor performances are responsible to MS-specific situation rather than to area wide status. The trouble can be expressed in accordance with statistical deduction and hypothesis testing, an attractive feature to explore. Additionally, the matching with mobility data will provide insight into the practice patterns and TCP performances of moving MSs for the period of handovers.

3. CONCLUSION

The above analysis shows that it is possible to build powerful filter indicators from performance parameters established by passive monitoring TCP traffic. In the specific case considered, all the indicators associated to re-transmission events are so effective that even the simplest testing method, i.e. a fixed threshold placed adequately set, would have provided early warning about the presence of the bottleneck several days in advance. Based on TCP performance indicators complements other methods, the revolutionary prospect of the propounded technique in view of the radio optimization method should be explicit in 3G Network at least to those who are having knowledge of the contemporary practice in this regard. Without using to the RAN appliances including that this approach is required but barely to the G_b/ IuPS near the SGSNs, typically co-located at a small number of physical sites. So far, it has established the likelihood to place a bottleneck connection within the Core Network from traces together with few vantage ends on G_n [6]. The MS-tracking has been already applied, separately for GPRS and UMTS, correspondingly on G_b and IuPS. The extension to the RAN, i.e. per-cell measurements of TCP, necessary some further developments to the analysis instrument (a customized edition of tcptrace) to operate cell report. In the linked poster some statement opening measurements of Retransmission Time Out (RTO) and TCP Round-Trip-Time (RTT) frequencies in particular GPRS cells, depended on past traces. The beginning outcomes specify that in GPRS the number of MS alongside active in the same cell is extremely low. This makes further challenge to discriminate performance degradation owing to cell circumstances from MS-specific troubles. A probable approach would be then to associate cell measurements across diverse times (days) and explore for signs of "recurrent" performance degradation.

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