

Research Article

Aggregated Self-Similar Traffic Parameters Determination Methods for EPS network planning

Qasim Nameer

Telecommunication systems department, 65029, Odessa National Academy of Telecommunications named after O.S. Popov, Ukraine.

***Corresponding author**

Qasim Nameer

Email: nameer.qasim@yahoo.com

Abstract: Essential to ensure the effective functioning of EPS (including LTE RAN) is planning efficiency of the network. It was from design methods, the adequacy of mathematical models used in this case, depend the properties and the viability of the future system. Recent studies of the properties of traffic in modern networks have shown that the use of models of self-similar processes can more accurately describe the traffic transmitted in these networks. Among the published works is a great lack of studies that focus on problems of parametric synthesis of telecommunication network based on the use of models of self-similar processes. In this article, we consider the solution of such problems as the choice of mathematical models of group and individual traffic in EPS network and method of determining flow parameters at their aggregation. Proposed expressions are correct both for self-similar traffic and for Poisson traffic case. As a result of simulation proved the accuracy of the proposed method of determining the traffic parameters when aggregate self-similar traffics. The error in determining the Hurst parameters does not exceed 2%. Other problems, as well as developing a method of parametric synthesis of EPC network will be considered in our future research.

Keywords: LTE, EPS, network planning, traffic, self-similarity, fractional Brownian motion, aggregation.

INTRODUCTION

LTE is in actuality an opportunity to re-imagine the mobile network as a dynamic platform for service delivery by leveraging software-defined networking (SDN). In contrast to the circuit-switched model of previous cellular systems, Long Term Evolution (LTE) has been designed to support only packet-switched services. It aims to provide seamless Internet Protocol (IP) connectivity between user equipment (UE) and the packet data network (PDN), without any disruption to the end users' applications during mobility. With native IP transport, theoretical data speeds approaching a gigabit and no circuit connection for voice/SMS, it's not hard to see why LTE will act as the catalyst to a true mobile Internet. Because it's a break from the "traditional" model, LTE opens the door to new thinking (and new vendors) to build the best mobile network for the next generation mobile experience.

While the term "LTE" encompasses the evolution of the Universal Mobile Telecommunications System (UMTS) radio access through the Evolved UTRAN (E-UTRAN), it is accompanied by an evolution of the non-radio aspects under the term "System Architecture Evolution" (SAE), which includes the Evolved Packet Core (EPC) network.

Together, the LTE RAN and the EPC can be referred to as the Evolved Packet System (EPS).

The RAN is responsible for all radio-related functionality of the overall network including, for example, scheduling, radio-resource handling, retransmission protocols, coding and various multi-antenna schemes. The EPC is responsible for functions not related to the radio interface but needed for providing a complete mobile-broadband network. This includes, for example, authentication, charging functionality, and setup of end-to-end connections. Handling these functions separately, instead of integrating them into the RAN, is beneficial as it allows for several radio-access technologies to be served by the same core network.

EPS uses the concept of EPS bearers to route IP traffic from a gateway in the PDN to the UE. A bearer is an IP packet flow with a defined quality of service (QoS) between the gateway and the UE. The E-UTRAN and EPC together set up and release bearers as required by applications.

EPS consists of several different types of nodes, some of which are briefly described below and illustrated in Fig.1.

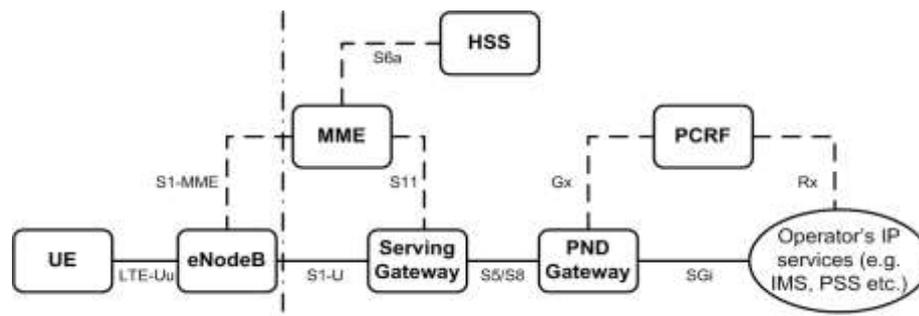


Fig-1: The EPS network elements

The Mobility Management Entity (MME) is the control-plane node of the EPC. The Serving Gateway (S-GW) is the user-plane node connecting the EPC to the LTE RAN. The Packet Data Network Gateway (PDN Gateway, P-GW) connects the EPC to the internet. In addition, the EPC also contains other types of nodes such as Policy and Charging Rules Function (PCRF) responsible for quality-of-service (QoS) handling and charging, and the Home Subscriber Service (HSS) node, a database containing subscriber information. It should be noted that the nodes discussed above are logical nodes. In an actual physical implementation, several of them may very well be combined. For example, the MME, P-GW, and S-GW could very well be combined into a single physical node. The LTE radio-access network uses a flat architecture with a single type of node – the eNodeB, which response is responsible for all radio-related functions in one or several cells.

Essential to ensure the effective functioning of EPS (including LTE RAN) is efficiency of network planning. It was from design methods, the adequacy of mathematical models used in this case, depend the properties and the viability of the future system.

One of the stages of network planning process is the choice of the parameters of structural elements, such as the bandwidth of communication channels, the volume of buffer used to service streams in the network nodes, and others. Modern research effort traffic in telecommunication network [1, 2] show that its statistical characteristics are different from those adopted in the classical queuing theory. Using the idea that combining a large number of flows from independent sources of information leads to a process described by a Poisson process, is not true. This leads to the fact that traditional methods of calculating the parameters of telecommunications systems and their probability-time characteristics, based on the Poisson model and the Erlang formula gives unduly optimistic results, leading to an underestimation of the load. Recent studies of the properties of traffic in modern networks have shown that the use of models of self-similar processes can more accurately describe the traffic transmitted in these networks.

Network performance degrades gradually with increasing self-similarity. The more self-similar the traffic, the longer the queue size. The queue length distribution of self-similar traffic decays more slowly than with Poisson sources. However, long-range dependence implies nothing about its short-term correlations which affect performance in small buffers. Additionally, aggregating streams of self-similar traffic typically intensifies the self-similarity ("burstiness") rather than smoothing it, compounding the problem.

Self-similar processes can detect in the following equivalent criteria [3]:

1. slowly decaying variance;
2. presence of long-term dependency;
3. presence of heavy-tailed distribution.

Among the published works in the direction of the study of self-similar flow there is a great lack of studies that focus on problems of parametric synthesis of telecommunication network with system-wide quality of service parameters based on the use of models of self-similar processes.

In this paper, based on the previously known self-similar traffic studies, conducted selection of mathematical models of group and individual traffic and proposed methods for determining the traffic parameters. These studies are an important part of the planning method for LTE and EPS networks, which will be considered in our future research.

Statement of the Problem

The process of planning LTE RAN and EPC network just like any other telecommunications network is a multi-step process, based on an integrated use of mathematical models of physical processes which taking place in it, as well as methods of synthesis based on the application of these mathematical models. One of the step of planning process is a parametric synthesis, which involves the determination of optimal values of elements in the known structure of the system.

Because streams that transmitted through the network has properties of self-similarity, this exerts a great influence on the performance of the EPS. Particularly important role it plays in parametric

synthesis of EPC network, providing the transmission of multimedia traffic and real-time traffic. Use for modeling of traffic in EPS models of self-similar processes in order parametric synthesis, highlights the need to address these particular problems:

- choice of mathematical models of traffic in different parts and levels of EPS network;
- development of methods for determining the parameters of the aggregate traffic, formed by combining traffic arriving at a processing node or transmitted together on a common links;
- determination of the calculated expressions that allow to relate the quality of service parameters with the parameters passed and served flows.

In this article, we consider the solution of such problems as the choice of mathematical models of group and individual traffic in EPS network and method of determining flow parameters at their aggregation. Other problems, as well as developing a method of parametric synthesis of EPC network will be considered in our future research.

Modelling of traffic in EPS network

Traffic in EPS network can be divided to two groups:

- traffic from single application and separate stream, such as EPS bearers;
- and group traffic which are the combination (after aggregation) of multiple streams.

We propose to use On/Off source model for modeling the EPS bearers traffic which coming from the single source. Traffic source, as described by On/Off model is a source that has two states (fig. 2): active (On-period) and passive (Off-period). In the active state, it provides a stream of constant speed λ_{On} . In the passive state traffic is not transmitted. In this model On- and Off-periods durations are random variable.

If interval duration activity and passivity described by exponential probability density functions then resulting traffic is not self-similar. For modelling of self-similar traffic we must use heavy-tailed distribution, such as Pareto distribution for activity or/and passivity interval. We also note that the distribution function $P_{On}(\tau)$ and $P_{Off}(\tau)$ may be different for the duration of active and passive period.

For modeling of group traffic we propose to use fractional Brownian motion model that proposed by Leland et al [1] and used by Norros [4, 5] to obtain expressions describing the qualitative characteristics of the service group self-similar traffic in the network nodes.

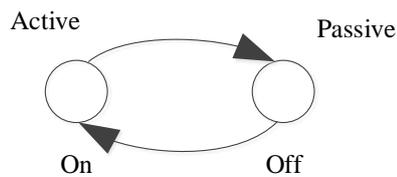


Fig-2:Model of individual traffic source

From the point of view of modeling of group traffic in telecommunications network communication channels fractional Brownian traffic is represented as

$$\xi(t) = \lambda t + \sqrt{\zeta \lambda} B_H(t), \dots \dots \dots (1)$$

where $\xi(t)$ is amount of data received by the interval $(0, t]$. Fractional Brownian traffic model has three parameters $\{\lambda, \zeta, H\}$ that describe the characteristics of such flows as real average flow rate λ , measured in the packet/sec or bits/sec, and that is a quantitative characteristic of the traffic, but also the parameters ζ (package·sec or bits·sec) and dimensionless quantity H that describes the qualitative characteristics of the traffic.

This traffic model has been considered and analyzed in many works [1, 2, 6], and others for various technologies packet-switched networks and for various telecommunication services. Comparison of this model with the characteristics of real network traffic have shown that the model of fractal Brownian traffic poorly describes the traffic intervals for small periods of time, but is well suited to describe the traffic at medium and high ranges.

Determination of parameters of aggregate network traffic

In [7] conducted a study and prove that the aggregated traffic that results from combining streams (EPS bearers) described by On/Off source, asymptotically tends to flow described by Brownian (or fractional Brownian) motion, and expressions are obtained to determine resulting flow parameters. This property is in good agreement with selected models of network traffic.

The calculation expressions, which fully described in [7] can be used to determine the parameters of the group traffic transmitted through communication link of telecommunication network that is part of EPS network. Described method allows to determinate of aggregated group traffic parameters (such as $\{\lambda, \zeta, H\}$) based on the known statistical parameters of On- and Off-periods (mean values and variances).

When solving problems of EPC network parametric synthesis is necessary to determine what properties will have aggregated traffic if one from merged traffic was self-similar, as well as on the properties of self-similar traffic affect queuing mechanisms in telecommunications network nodes.

Study of the properties of aggregated self-similar traffic engaged a large number of researchers using research methods as real networks and their mathematical models. In [8], using analytical models of self-similar traffic are given and proved a series of assertions. On this basis, we can conclude that as a result of aggregation of two streams, where at least one has the property of self-similarity, the resulting traffic is self-similar too. Taking Hurst parameter $H = 0,5$ for the traffic with short-term dependence (not self-similar traffic), for resulting traffic that obtained as a aggregation of several traffics we can be write

$$H = \max_i(H_i), i = 1, \dots, N. \dots\dots\dots (2)$$

Expression (2) can be used to estimate the Hurst parameter of the aggregated traffic. For other parameters of aggregated traffic, such as rate λ and coefficient of variance ζ , the following expression

$$\lambda = \sum_i \lambda_i, \dots\dots\dots (3)$$

$$\zeta = \frac{\sum_i \zeta_i \lambda_i}{\sum_i \lambda_i} \dots\dots\dots (4)$$

Addition to the above method for estimating parameters of the aggregated traffic important for solving problems of EPS network parametric synthesis has impact assessment mechanisms queue processing in the network nodes on the traffic characteristics with the effect of self-similarity.

As a result of the work [9] studies for the system described above is formulated and proved a theorem which states that self-similarity property for strictly asymptotically self-similar traffic are not changed as a result of expectations of service in line with any discipline of service, if the process of describing the queue length has finite second moment.

Based on this theorem, we can draw the following important conclusions for practice [9]:

1. As a result of the processing of the incoming flow to the node with the property strictly asymptotically self-similar process saved not only his self-similarity, but also remains unchanged Hurst parameter H .

2. Assuming finite second moment of the queue length distribution, we can use mechanisms to dynamically allocate bandwidth communication channels or other mechanisms to guarantee quality of service, and it does not change the properties of a self-similar flow. In practice, the buffer size and queue length is limited, and therefore this condition is satisfied.

Discovery the proposed traffic parameters determination algorithm

The adequacy of described above calculation expressions check using by simulations. For this purpose we will conduct our experiment by the following procedure:

1. Collection of data on the traffic that is transmitted over a cellular (LTE) network and forming trace files.
2. Traffic analysis, determination of its parameters, parameter Hurst (degree of self-similarity).
3. Creating a simulation model of the network (ns-2) comprising a set of traffic sources, aggregation node and destination node. Traffic, which described by trace files that are obtained from the observation on the first stage, is input to the model.
4. Traffic capture in the destination node, an analysis of its characteristics and their comparison with the calculated results.

Consider these steps in detail.

We use a laptop with connected cellular modem to collect data about traffic, which transmitted over a cellular network. Hereinafter we initiated traffic, when accessing the Web, transfer video streams, email, Vo-IP, file transfer, P2P-traffic.

Data about transmitted packets fixed by using packet analyzer Wireshark. On the basis of data collected through the Wireshark are generated trace files for the ns-2 simulation model. Trace files contain information about intervals between packages and their length.

Additionally, we form the data files about traffic intensity. To do this, we divide the time series into intervals by 1 sec and we calculate quantity of data transmitted during each interval. These files are used to determine the statistical traffic parameters such as: mean value, coefficient of variance and Hurst parameter for each traffic.

We use the R/S-analysis method [3] for determination the Hurst parameter value. This method based on that Hurst parameter value can be found as

$$H = \frac{\log(R/S)}{\log(L)} \text{-----(5)}$$

where R/S the corresponding value of the rescaled range; L is the duration of the sample data.

For calculating of Hurst parameter value we used of Matlab. The program on Matlab for calculating traffic parameters is shown below

```

% Import the data
pnl = load('a1.txt');
% Calculate mean value
mv= mean(pnl);
disp(mv)
% Calculate coefficient of variance
disp(var(pnl)/mv)
% Start looping
N=length(pnl);
for n=2:N
% Calculate R statistic
Deviation=cumsum(pnl(1:n))-
cumsum(ones(n,1))*sum(pnl(1:n))/n;
R(n-1)=max(Deviation)-min(Deviation);
% Calculate S statistic
S(n-1)=sqrt(sum(pnl(1:n).^2)/n-
(sum(pnl(1:n))/n)^2);
% Calculate R/S statistic
Q(n-1)=R(n-1)/S(n-1);

```

```
time(n-1)=n;
```

```
end;
```

% The Hurst exponent is derived by plotting $Q(n)$ as a function of

% $\log(n)$ and fitting a straight line. The slope of the line gives H

```

plot(log(time),log(Q),'b-')
hold on
fit=polyfit(log(time),log(Q),1);
H=fit(1)
plot(log(time),polyval(fit,log(time)),'r-')

```

Traffic intensity files analysis showed that Hurst parameter for some sessions (such as FTP) close to 0.5, it means that this traffic is not self-similar. For other sessions Hurst parameter lies within the range $H = 0.7..0.9$, it means that traffic is self-similar.

Simulation modeling carry out with help of NetworkSimulator – 2 (ns-2) software suite. Scheme of the simulation model is shown in fig. 3.

Modeled network contains switching node N_{sw} , which aggregate incoming traffic from set of source-nodes $n_i, i = 1 .. N$. Traffic which aggregated in N_{sw} transmitted to destination node N_D by common link from N_{sw} to N_D . Traffic which received in N_D saved in trace file for statistical analysis.

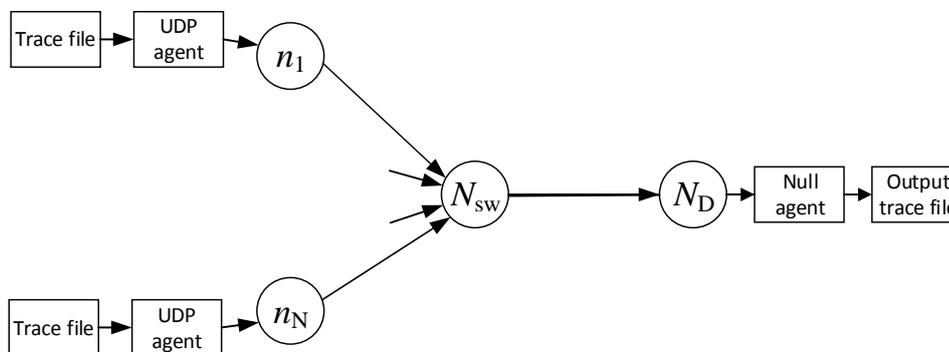


Fig-3:Scheme of the simulation model

Simulation OTCL-script described below. In first part we create simulation object, output trace file, switching and destination nodes, connect it and define finish function.

```

# Create simulator object
set ns [new Simulator]
# Create output trace file
set f [open out.tr w]
$ns trace-all $f
# Define stop time moment
set stoptime 600.0

# Procedure 'finish'
proc finish {} {

```

```

global ns f
# Close trace file
$ns flush-trace
close $f
# Exit
exit 0
}

# Create switching and destination nodes
set Nsw [$ns node]
set Nd [$ns node]
# Connect switching and destination nodes by duplex link
$ns duplex-link $Nsw $Nd 5Mb 25ms DropTail

```

In next part of file we must for each source node create model node, connect it to switching node by duplex link, create UDP agent, create traffic source which obtain data from trace file, define destination for each source. Input trace file for each source is trace file obtained by Wireshark packet analyzer.

```
set n1 [$Ns node]
$Ns duplex-link $n1 $Nsw 2Mb 10ms DropTail
```

```
set tf1 [new Tracefile]
$tf1 filename trace_1.dat
```

```
set s1 [new Agent/UDP]
$Ns attach-agent $n1 $s1
```

```
set d1 [new Agent/Null]
$Ns attach-agent $Nd $d1
```

```
$Ns connect $s1 $d1
```

```
set tr1 [new Application/Traffic/Trace]
$tr1 attach-tracefile $tf1
```

```
$tr1 attach-agent $s1
$Ns at 1.0 "$tr1 start"
$Ns at $stoptime "$trace3 stop"
```

Last part of file we call function “finish” at stop time moment and run our model.

```
$Ns at $stoptime "finish"
$Ns run
```

Data, which saved to output trace file, used for determination traffic parameter (such as mean value, coefficient of variance and Hurst parameter) by Matlab program usage which shown before.

This experiment repeated three times for different sets of input trace files. Traffic parameters obtained after simulation compared with the parameters calculated using the proposed method. Traffic rate value, obtained by simulation equal to the calculation value for all experiments. Meanwhile the value of Hurst parameter that obtained by calculation differs from simulation value. So in the first experiment calculation Hurst parameter value was $H=0.75$ and simulation value $H=0.73$. In the second case we got value $H=0.71$ and $H=0.74$ respectively. In the third experiment we got value $H=0.79$ and $H=0.78$ respectively.

In the last experiment we have aggregate self-similar and not self-similar traffic and as result we got traffic with Hurst parameter value $H>0.5$ it means that aggregation of self-similar and not self-similar traffic forms self-similar traffic.

Comparison results shown that the experimental data agree with the results of calculations using the proposed method, which enables to conclude about the adequacy of the mathematical models and the calculation method. Small deviations from the calculated results of the experiment are statistical data related to the limited sample size.

CONCLUSIONS

An important task in parametric synthesis of telecommunications network such as EPS network is to determine traffic parameters when aggregating and jointly transmitting through communication links. In this paper, presented methods, which can determine the parameters of the aggregate traffic for the case of combining self-similar traffic described by model of fractional Brownian motion. Proposed expressions are correct both for self-similar traffic and for Poisson traffic case. As a result of simulation proved the accuracy of the proposed method of determining the traffic parameters when aggregate self-similar traffics. The error in determining the Hurst parameters does not exceed 2%.

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