PACKET LEVEL PERFORMANCE EVALUATION OF NG ALL-IP NETWORKS

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To date the Internet and wireless communications have been evolved as *separate technologies* because of different types of traffic they were intended for. Nowadays, with commercial launch of 3G networks, the convergence of these technologies is getting clear. While next generation (NG) or 4G mobile systems are not well defined, there is a common agreement that they will rely on IP protocol as an end-to-end transport technology. The motivation is to introduce a unified service platform and transport facilities for future composite mobile Internet known as NG All-IP network.

In addition to broadband wireless access to the Internet, *NG All-IP networks* must satisfy requirements of *QoS*-aware applications. This is an inherent problem for many service types even in fixed networks. *Wireless and mobility* issues *add* their own *problems* on top of this inherent IP flaw. *Time varying characteristics of wireless channels, teletraffic and mobility issues of mobile users must be addressed before wireless Internet services will be commercially deployed.* Thus, the intention to adopt IP protocol for future mobile environment and subsequent extension of packet-based services to the air interface calls for novel advanced performance evaluation methods.

Survey of *wireless channel models* shows that large-scale propagation models proposed in literature, whether outdoor or indoor, predict a received local average signal strength (RLASS) at a given distance from the transmitter and *do not take into account neither mobility* of users between areas with different RLASS *nor rapid fluctuations of the received signal strength*. Small-scale propagation models developed to date, both indoor and outdoor, predict rapid fluctuations of the received signal strength over very short travel distances or short time durations. Those models implicitly capture mobility of the user up to the short travel distances only, and are not appropriate when mobile user moves over large distances. *Novel wireless channel models must capture* propagation characteristics as a function of user's mobility and could be represented by stochastic processes.

However, even *adequate models* of received signal strength are still not appropriate for performance evaluation purposes and *must be further extended* to higher layers providing, for example, IP packet error probabilities. Thus, we have to take into account characteristics of underlying layers including data-link FEC, ARQ hybrid FEC/ARQ and modulation schemes at the physical layer. Hence, an adequate *wireless channel model* at a given layer *is a complex cross-layer function* of underlying layers, propagation characteristics and mobility of the user.

Traffic models designed for conventional second generation 2G mobile systems do not explicitly take into account mobility behavior of single user. Most of them assume a stationary behavior of large populations of users and try to capture session level parameters by distributions like exponential one or its mixtures. Those models *are not concerned with per-user granularity*, and therefore, cannot capture correlation properties between mobility behavior of single user and its teletraffic demands. It may be the case that if one does not take into account these correlations the necessary capacity of the system may be overestimated or underestimated which leads to one of the undesirable effects: unwarranted investments or unsatisfactory service quality. Due to this reason, the focus of users' teletraffic modeling should be extended to include the dependence of single source models at both session and packet levels on mobility behavior. Due to high popularity of TCP, modeling loss-constrained applications we also have to take into account its behavior and the transport layer.

In our study *we develop* an extensions of performance evaluation method based on *novel approaches* to wireless and traffic modeling. We explicitly capture mobility behavior of the user between areas with different propagation characteristics using a simple translation of 2D movements into 1D Markov chain. The model consists of two different parts: mobility model and model of wireless channel. Wireless channel model captures large-scale propagation characteristics and represented as a function of the mobility model. For this model *we provide* three different *parameterization techniques* using information or real measurements of received signal strength or classic propagation models available in literature.

We also developed an integrated traffic model of single source at the session level consisting of two different parts: mobility model and teletraffic model. The mobility behavior of the user and session level teletraffic characteristics are represented by Markov chains with finite state spaces. Both models are integrated, so that the whole model can be seen as doubly stochastic process while does not lead outside one-dimensional Markov chain. This is due to the special superposition of both parts, which makes a teletraffic part a probabilistic function of mobility one, i.e. transition probabilities of Markov chain modeling teletraffic part depend on the state of Markov chain which represents mobility behavior of the user. *Our model is not limited to certain application* and can be extended to capture session level characteristics of various sources.

To evaluate performance of packet based applications running over the air interface we firstly extend provided small-scale propagation model representing the received signal strength of wireless channel to IP layer using cross-layer mappings. The new model represents IP packet error probabilities and retains all memory properties of initial process. Then, we replace the wireless channel model at the IP layer by artificial equivalent arrival process using error-arrival mapping. We use this process together with arrival process modeling user's traffic source as an input to queuing system with deterministic service time, limited number of waiting position and special service rules representing the packet service process of the wireless channel.

Specific *applications of the outlined approach* include the following – design and evaluation of data-link error concealment techniques, mobile terminal buffer dimensioning, optimization of link layer parameters, performance evaluation of QoS degradation etc. The proposed approach is analytically tractable and *can also be used in simulation studies*.