End-to-end Simulations of Heterogeneous Radio Access Systems

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Motivation

It is foreseen that the future of mobile systems will be made of **cooperating radio access technologies**, such as Cellular, WLAN or Digital Broadcast. This vision is widely shared under the appellation "System Beyond third Generation". Each radio systems will bring its specificity and advantage to provide efficiently to the ensemble enhanced features. Naturally, these radio access systems are going to be plugged onto an IP-based core network: interconnection between mobile operator domains, service provider domains, content provider domains and even user domain is going to be IP-based.

In order to assess realistically the end-to-end performance of such composite environment, made of various radio systems as well as fixed network, system designers must develop original simulation techniques or at least adapt well know simulation techniques to this novel environment. In addition, for properly allocating the radio and core network resources of these complex heterogeneous systems, the network operator(s) should take into account several parameters. Management actions should be properly assessed before their application into the real networks. For that purpose, advanced management platforms should be developed, including necessarily simulators engines in order to help finding the most appropriate management actions.

Both for designing or operating B3G systems, efficient simulation techniques are required. Therefore, end-to-end simulation is identified as an important research area in the context of future wireless communications.

An example of way forward

In the following, we present a **Network and Environment Simulation tool (NES)** that can be used during the system design phase or as a support to any management platform suited to the B3G context. The presented approached has been validated in the FP5 EU project MONASIDRE [1].

Following the example of B3G systems where each radio system bring its benefit, without trying to overlap with the features of other radio systems, we decided to use a **heterogeneous simulation approach**, i.e. to make different kinds of simulator cooperate together. This approach has the main advantages to be open, flexible and scalable. It obviously prevents from the development of a single, large, and often inefficient simulator aiming at covering all the aspects of the end-to-end simulation.

On the other hand, one could say that it is time consuming to develop from scratch as many simulators as simulated systems or scenarii, arguing that a single simulator, as long as it is well structured (e.g. object oriented based), could easily handle the complex simulations required by B3G systems. Such arguments are also perfectly understandable.

As a result, the proposed approach would be an intermediate one, between the single simulator and the aggregation of two many specific simulators. It is the reason why in [1], the NES tool was split into two sub-simulators.

The first sub-simulator is dedicated to the simulation of the IP core network and is based on the well-known event-driven Network Simulator (NS) [2] that have been modified. The reuse of existing tool, even if modifications are required, leads to a considerable gain in terms of development and validation time. It should be noted that NS allows to simulate several management domains in a same simulation process.

The second sub-simulator is dedicated to the simulation of radio systems. Several versions has been tuned to the different considered radio access systems (Cellular, WLAN, Digital Broadcast), but keeping the same core engine, whose structure was, indeed, inherited from an event-driven radio planning software. Hence, three instances of the radio simulator run in parallel for simulating the three radio access systems.

In the following, the sub-simulator dedicated to the simulation of fixed part is called IP-NES while the simulator dedicated to radio simulation is called the Radio-NES.

The main issue was to make the two discrete event sub-simulators communicating together without loosing their internal time/event representation. Moreover, any simulated data communication must be derived in the two sub-simulators, generating linked events.

For that purpose, a **master/slave concept with a pseudo-time synchronization of the two simulators** was considered. The IP-NES was the slave of the Radio-NES: the calls were generated/terminated by the Radio-NES, leading to the creation of the corresponding event in the IP-NES, for uplink and downlink calls.

The Figure 1 represents the NES overall architecture, showing the basic components: the IP-NES and the 3 types of Radio-NES, each one corresponding to a particular RAT.

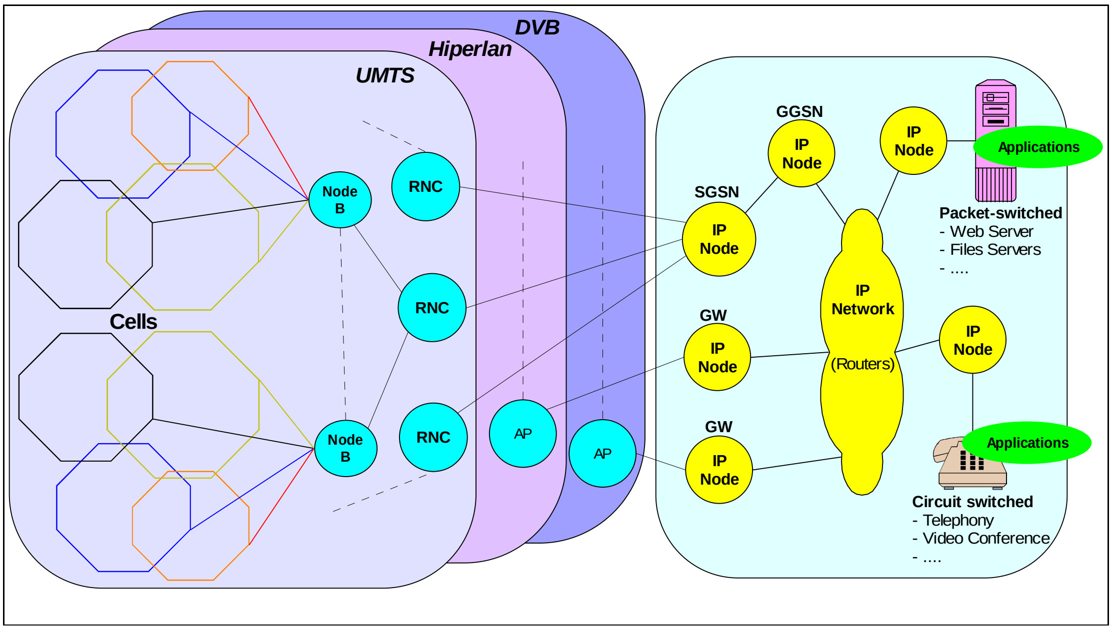

Figure 1. NES overall architecture

To allow the IP-NES executing on demand request from the Radio-NES and/or the B3G platform, it was mandatory to modify NS that is originally script-based: the simulation to be executed is theoretically described in advance in a script file. Then, the outcome of the simulation is written in another file that can be played back in a visualization software, Network Animator (NAM) [3]. This way of running the simulation implies that the simulator user knows in advance the lists of events to simulate. It also implies that neither modification of the network topology, management action or unscheduled traffic is allowed during the simulation. In order to overcome this limitation, **NS was modified to allow external interactions when simulation is running**. Several "input pipes" have been added in which commands can be inserted during the simulation, as depicted in the Figure 2.

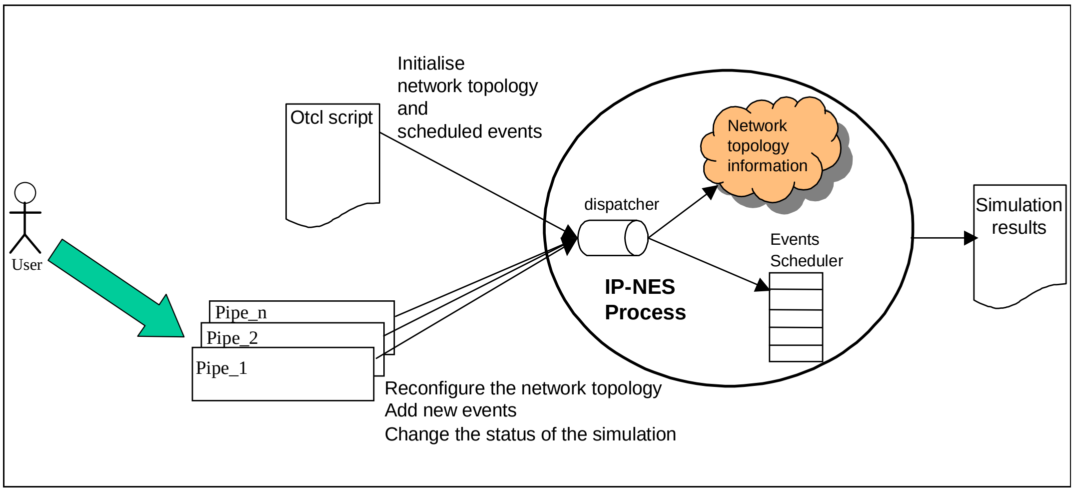

Figure 2. Modified NS architecture

Similarly, **NAM has been modified to allow "real-time" visualisation of the IP-NES**. For that purpose, a pipe mechanism has been added to NAM that feed the visualisation tool with the events to be shown.

Regarding the visualization of the Radio-NES part, a specific GUI written in Java was developed, showing in "real-time" what happened in Radio-NES. The synchronization between the visualization interfaces was ensured by the intrinsic synchronization between IP-NES and Radio-NES.

Conclusion

Complex simulators will be needed to design and even operate heterogeneous radio systems. Instead of developing a proprietary unique tool, we promote the idea to interconnect several simulators, using as far it is possible open source core simulation engine.

The paper presented the interconnection of two simulators, one dedicated to radio environment that could be derived for representing the various radio access systems, and the second simulator is dedicated to simulation of IP networks and was built on the public NS software. Validated in [1], our approach leads to efficient simulations that allow dynamic responses of the B3G management platform prototype when facing congestion event or simple requests from service provider.

Of course, other examples of combining simulators exist: for instance, link layer simulations including physical layer features (power control, MIMO etc…) could feed network level simulation, through for instance raw results tables of accurate models of links.

References

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