# Routing in Third Generation Telecommunication Networks

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## Abstract

After the success of mobile telecommunication networks introduced by the global system for mobile communications (GSM), the promise of the next generation of mobile technology is to bring data access to the mobile terminals with good data transmission rates and good quality. That initial requirement has led to bringing the Internet Protocol (IP) router at the core of the telecommunication infrastructure. This paper looks at third generation (3G) telecommunication networks, the way traffic over IP is introduced in this kind networks and examines the routing problem in this setup. Solutions for this interdisciplinary problem come from many different directions, from the IP world as well as from the telecommunications area, while in the same time new convergent solutions start to be defined.

## 1 Introduction

The introduction of mobile technology was a big market success. GSM set up the framework for the so called second generation digital cellular networks. The technology evolved and brought to the end-users more services on top of the basic voice service. One popular example of such a service is the short message service (SMS). The next natural steps were making Internet available from the mobile terminal as well as offering the possibility to use a multimedia messaging service (MMS) to expand the messaging capabilities of SMS by adding pictures and music. The limitations of GSM showed up at this point, mostly due to limited bandwidth offered to the end-users. That was the main driver behind the specification of the next technological evolution, the 3G telecommunication network. The new technology is an evolution from GSM which specifies new radio access technologies for the radio access network (RAN) and in the same time introduces new network elements (NEs) designed for data handling and routing. [15]

The evolution from 2G to 3G was however not a direct one, but had an intermediary phase known as the General Packet Radio Service (GPRS). The purpose of GPRS is to facilitate the communication between wireless networks and external data networks, like the Internet or any other IP based networks. [5]

The standardization body responsible for the 3G specification is the 3rd Generation Partnership Project (3GPP) and it has created more subsequent release of specifications. There are differences in the network architecture and functionalities between these releases, therefore it is good to mention here that this paper follows the specifications from Release 5 of 3G. [3]

The paper examines the specificities of routing in 3G networks and starts with an overview of 3G network architecture with an emphasis on NEs with routing functionality. After that it moves on to routing and typical router architecture and functionality in the Internet. Next it looks at particularities of routing in the 3G network environment, with a closer look at capacity, throughput and high-availability requirements. In the same time special attention is paid to routing protocols used in this context.

## 2 3G Network Architecture

The network infrastructure comprises two main parts, the Radio Access Network (RAN) and the Core Network (CN). The Radio Access Network consists of Radio Network Systems (RNS) made up by Radio Network Controllers (RNCs) and Node Bs.

In its turn the Core Network is further divided into an IP Multimedia Subsystem (IMS), a Circuit Switched (CS) domain and a Packet Switched (PS) domain. IMS is a collection of network elements that provide the IP multimedia related services, like text, audio, video. The data related to these services is further transmitted through the PS domain.[4]

For the purpose of this paper the focus is on the PS domain of the Core Network, because that is the part where IP based communication and routing take place.

The CN domains, CS and PS, are different from each other in the manner in which user traffic is supported. A "CS type of connection" [4] is a traditional telecommunication style connection with dedicated resources allocated for the duration of the connection. In contrast, in a "PS type of connection" [4] the information is transported in packets ("autonomous concatenation of bits" [4]) and each packet is routed in a distinct and autonomous fashion [4]. This is where IP based routing enters the world of telecommunications.

The network elements specific to the PS domain are the Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN). The purpose of the SGSN and the GGSN is to facilitate the interworking with external data networks, more specifically with IP based networks or other Public Land Mobile Networks (PLMNs) [5]. For example when the end-user requires access to an IP network like the

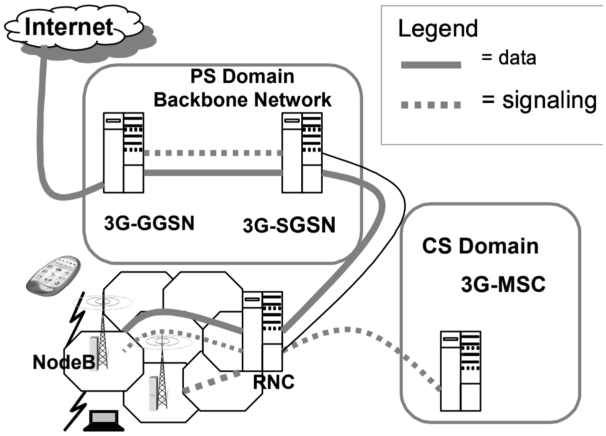


Figure 1: The 3G Network Architecture with an emphasis on the data path. Routing functionality is present in the RNC, the SGSN and the GGSN. [5], [4]

Internet interworking with the Internet is required. On the other hand when the end-user wants to transmit multimedia audio or video to another end-user the type of internetworking used is between 2 PLMNs. In both of the above cases the interworking is handled by the SGSN and GGSN.

Figure 1 illustrates this architecture and highlights the data path that starts from the mobile terminal, goes through the RNC and then through the SGSN and GGSN to finally reach the Internet.

### 2.1 Control and User Plane Processing

Already starting with GPRS, the functionality of the NEs was divided in two planes, one known as the control plane and the other one as the user plane. The NEs will thus employ distinct user and control plane protocol stacks to interact with each other.[13]

The control plane processing is responsible for the maintenance of state information needed for forwarding. In order to accomplish this task it needs to maintain routing tables and to run routing protocols for that purpose. Additionally, session management, mobility management as well as Quality of Service (QoS) management are all part of the control plane processing. The control plane is also known as the signaling plane and it is used to exchange signaling information between NEs. [13]

The user plane processing handles the forwarding of user data by using packet forwarding, address resolution and IP header manipulation. The handling of the QoS is done here, whereas we have seen that QoS management is part of the control plane [13]. The data packets are transported over the user plane, for example between SGSN and GGSN the packets are being tunneled by using the GPRS Tunneling Protocol (GTP) [6].

Table 1 presents a comparative picture of the requirements that arise from the control and user plane functionalities described above.

| Control Plane | User Plane |
|---|---|
| Relaxed time requirements | Hard time requirements |
| Low throughput | High throughput |
| Data structure maintenance | Fast packet forwarding |
| Call/Session management | Stateless or stateful processing |
| Routing table maintenance | Address resolution (table lookup) |
| QoS management | QoS handling |
| Mobility management | Firewall functions |

Table 1: Control plane versus user plane requirements in 3G networks and their impact on routing

## 3 Routing and Routers in the Internet

Routing is an essential part of the Internet and it is defined as the process of finding a path (a route) to send a packet from its source to its destination [13]. However finding just a route is not enough for ensuring optimal traffic exchange between two nodes, it has to be an optimal route. What exactly optimal route means depends on what is considered most important for a particular type of traffic [14]. For example in case of real time video conferencing the routes with minimum delay are optimal, while in case of data transfer the routes with no data loss are the selected ones. Therefore routing is concerned with finding the best possible route between any two nodes, the one with the lowest associated cost.

All routes known to a router together with their associated cost are stored in a table, namely the routing table. In case of small networks this table can be statically configured by filling manually the routing tables. But when the networks scale up the tables become too big and it is too hard, if not impossible, to keep up to date statically. This problem is solved by using routing protocols that offer a dynamic and distributed solution to optimal path finding. [13]

The routing protocols are designed to adapt quickly to network topology changes such as link failures or route cost changes. A larger network is divided into smaller domains known as Autonomous Systems (AS) [7]. The protocols operating inside an AS belong to the Interior Gateway Protocols (IGP) category, like Routing Information Protocol (RIP) or Open Shortest Path First (OSPF) protocol. In their turn Exterior Gateway Protocols (EGP) are used between autonomous systems, with the most known example being the Border Gateway Protocol (BGP)[13].

### 3.1 The OSPF protocol

Open Shortest Path First (OSPF) is a shortest path first (SPF) or link-state protocol. OSPF is an interior gateway protocol that distributes routing information between routers in a single autonomous system. OSPF chooses the least cost path as the best path [7]. In a link-state protocol, each router maintains a database describing the entire AS topology, which it builds out of the collected link state advertisements of all routers. Each participating router distributes its local state (i.e. the router's usable interfaces and reachable neighbors) throughout the AS by flooding. Each multi-access network

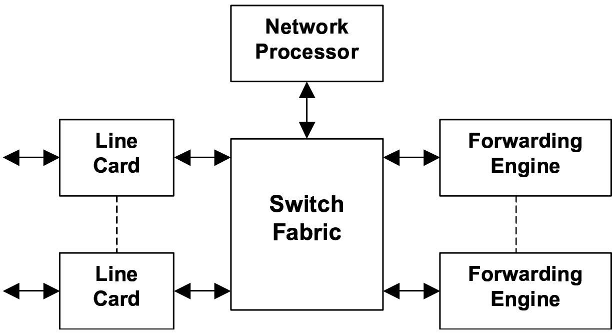


Figure 2: Architecture of a a high-speed router [10]

that has at least two attached routers has a designated router and a backup designated router. The designated router floods a link state advertisement for the multi-access network and has other special responsibilities. The designated router concept reduces the number of adjacencies required on a multi-access network. [7],[14]

### 3.2 IP Router Architectures

Historically the first generation routers had a centralized architecture with a central processing unit (CPU) that had to process all packets passing through the router. The processing load on the central CPU has become a major limitation for this model and has led to the development of the next generation of routers with a distributed architecture. This is the basic framework architecture used by most high-performance routers. [9]

The main functional blocks that form a high-speed router are the line cards that offer the interface to external data links and handle physical processing, a network processor where routing protocols run and compute the routing table, forwarding engines that use the the IP header to distribute the packets to the line cards, and a switch fabric to interconnect all these components [10]. Figure 2 illustrates this architecture [10].

## 4 Routing Solutions in 3G

One difference from the routers present in the Internet, is that in a 3G network the routing functionality is embedded into a Network Element. Thus, the network element will not be a pure router, but will have other specific functionality as well.

As Patil et co point out, 3G cellular networks represent some of the most complex systems to be implemented on a large scale that provide mobility, paging, addressing, security, accounting [13]. The nature of these services has brought new requirements for network elements with routing capability in terms of high-availability, scalability, mobility and quality of service.

Part of the problems are addressed as part of the internal architecture of the network element and the solutions are mostly propriety of the manufacturer. It is still essential to keep in mind the specificities of routing when these solutions are designed.

Another aspect of the solution comes from the developments done to the IP protocols themselves. In order to ensure routing for mobile hosts, sessions and applications on the mobile device must not be interrupted when the device changes the attachment point to the network, in other words seamless mobility is required. The solution for this problem comes from the IP world with the design of the Mobile IP protocol that tackles IP layer mobility [13].

A recent development in this area is the specification of the Advanced Telecommunication Computing Architecture (ATCA), which is a specification effort targeted to specifically fulfill the requirements of next generation carriers [2]. It is not an alternative to the 3GPP specifications, but it goes deeper with the architecture specifications into parts that are now manufacturer specific. Among the participants in this initiative there are manufacturers coming from either the traditional telecommunication industry or from the personal computer (PC) industry. In a published Intel white paper it is claimed that the proposed solution offering standard interfaces and modular software will bring benefits to the network operators by giving them the flexibility to easily add new services on their initial framework, once that framework is ATCA compatible [11]. Of course that statement has a lot marketing content, but the technical idea behind the ATCA concept is a very interesting one. This is certainly a development to follow closely and see weather the telecommunication industry can be influenced by the modular model that has become the standard in the PC industry.

## 5 Conclusion

The convergence between telecommunication networks and the IP domain has raised awareness to new problems, one of them being the way to insure optimal routing while still performing the specific telecommunication tasks and following availability and performance requirements.

In order to properly address routing issues in 3G networks it is essential that both 3G and IP domains are thoroughly studied. This is no easy task since both these domains are really complex pieces of communication systems.

While solutions have come from both of these domains, there is a growing tendency to converge these efforts, an example of this cooperation being the ATCA initiative. However there is still room for more interdisciplinary research and standardization in this area. It is also interesting to see how the 3G networks will be rolled out and what will be the feedback from the end-user. I expect that the requirements for availability, throughput and performance will be further refined as a result of this process.

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