# Enabling Modern Telecommunications Services via Internet Protocol and Satellite Technology

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**Abstract**

A classic problem is encountered when trying to deliver modern telecommunications services at affordable prices to geographically disperse and/or low-density communities. Historically these populations simply do not get the services. Mandates for Universal Service as part of global deregulation of the telecommunications sector is creating new demand for viable solutions to this problem. This paper discusses real world challenges and solutions to the problem through the application of Internet Protocol (IP) and satellite technologies with emphasis on the deployment of a patent pending distributed GSM mobile telephony network architecture.

## 1.0 Introduction

The Internet revolution of several years ago had dramatic effects on the telecommunications industry. Massive investments in the development of IP based equipment for mainstream requirements resulted in the ability for a single IP transmission network to carry multiple services. A second effect was a tremendous build out of the worldwide transmission network (including satellites), resulting in "limitless" bandwidth availability at low costs. A primary outcome of this has been that both legacy services (e.g., telephone) and new ones (e.g., broadband) can now be supported on a single transmission network and offered at low costs.

A secondary effect of this revolution has been that a host of new tools are now available to create solutions to solve the classic rural communications problem and provide equivalent services to the previously "disadvantaged" subscribers of the world (these subscribers being disadvantaged only because of where they live).

This paper discusses concepts and challenges involved with creating an all IP network via satellite designed to support multiple telecom services to serve remote locations. The example of a network provided for the Kingdom of Tonga is used to illustrate a modern network requirement, and its associated challenges and solutions.

## 2.0 Network Requirement

It is cost prohibitive to provide standalone transport for different telecom services. By adapting all services to a single format (i.e., IP) a common transport system which combines all the traffic can be created. In smaller markets this sharing of resources can have a significant effect on reducing network operations costs and thus the viability of the operator.

The expectation of the services that a network is to provide today is far greater than in the past. As a case in point, the example of a network provided to the Kingdom of Tonga is given. The network requirement was to provide GSM mobile telephony, digital television, and wireless broadband IP data services via a common IP network to several island groups within the kingdom. Due to the distance between the islands and the size of the market, a satellite-based solution was the only viable approach, and a traditional cellular network architecture would not be cost effective. A conceptual diagram of this network is given in Figure 1.

The solution was to provide a network architecture based on the integration of multiple technologies consisting of

- A distributed packet-based GSM network
- An IP-based satellite network including bandwidth on demand (BOD) capabilities
- A terrestrial digital television distribution network
- A broadband point-to-multipoint (PMP) wireless data distribution system
- A complete remotely managed network operations, administration, maintenance and provisioning (OAM&P) capability

## 3.0 Technologies & Protocols

As each network technology has its own protocols, the integration of multiple technologies to create an end service to the subscriber (e.g., the GSM phone service) results in the concatenation of multiple protocols. Particular attention must be paid to this concatenation if the network and its services are to be successful. This concept is further developed below in order to illustrate the resultant GSM solution.

## 3.1 Internet Protocol

Mass interest in the Internet has created enormous investments in routing equipment and a continuous drive to provide all telecommunications services over the Internet. The result of this is to be powerful, inexpensive, and flexible equipment, along with adaptations of the protocol itself to handle all services efficiently. However, although IP is often thought of as the common method upon which all services coexist, it must be realized that it is a collection of multiple protocols for multiple services sharing a common transport platform (a.k.a. the IP “cloud”). As a result, one protocol or service will affect another, and care must be given to the interactions and tradeoffs between these services if an acceptable quality of service (QOS) is to be maintained throughout the network.

A better description is that all communication services are encapsulated in an IP format. This IP format allows the use of standard open protocol equipment to create service offerings, and enables the sharing of the cloud by all the IP conditioned services. If well engineered, the advantages of sharing the IP cloud significantly outweigh any inefficiencies associated with conditioning the service to carried in IP format (i.e., the IP packet overheads).

### 3.2 Mesh Connectivity

In general communications are most efficient when mesh connectivity exists (i.e., where there is a direct connection between the source and destination). IP connections have an inherent mesh quality in that the network will typically route the packet to its destination via the shortest route. In addition, IP communication has inherent Bandwidth-On-Demand (BOD) and prioritization functions allowing the sharing of bandwidth between the various services and network nodes while still providing quality of service mechanisms. With the network services in an IP format, this mesh advantage can be utilized to minimize the amount of required bandwidth for the network, which is a significant recurring operations cost.

This advantage is taken a step further in the satellite network. Through the proper use of geostationary satellite technologies incorporating BOD techniques, an additional level of efficiency is achieved in maximizing the utilization of the satellite bandwidth. Furthermore, it should be realized that the IP network cloud encompasses the complete satellite coverage footprint, allowing the sharing of the satellite resource and network services across a large geographic area on a distance insensitive basis.

### 3.3 Softswitches

Some of the latest developments in telephony are centered on software-based switches (“softswitches”). These switches do not require physical connection between the control element of the switch and the physical hardware that switches the communication circuits. IP based softswitches are also now available along with IP versions of other network elements, and are an excellent candidate to address distributed switching requirements.

The remainder of this document concerns itself with the application of an IP based GSM softswitch over a satellite IP cloud. However it is noted that the discussions contained herein can largely be applied to CDMA based cellular networks as well.

# 4.0 IP GSM Softswitch Network

## 4.1 Network Architecture

A general network block diagram of the system architecture is shown in Figure 2. The diagram depicts the system components which constitute a solution to provide GSM cellular telephone service to select areas via satellite. A single centralized Network Switching Subsystem (NSS) and Operational Support Subsystem (OSS) is deployed. This NSS/OSS connects to any number of Radio Access Networks (RANs) via IP satellite connections. Each RAN consists of the necessary equipment (e.g. base stations) to provide mobile phone service in the local region. The RAN can also provide the interface to other local wireline or wireless networks that may be present.

Some of the features and benefits resulting from the use of this technology are summarized below.

- ***IP Format*** – GSM communications are carried in an IP format. This IP format allows the use of standard open protocol equipment to create service offerings, and enables sharing of the common transmission backbone with other IP based services, such as Internet access. Furthermore the fully meshed nature of an IP network allows for single hop communication between network nodes (i.e., traffic is automatically routed to its destination via the shortest route).

- ***Distributed Architecture*** – The resultant effect of an IP-based softswitch is that GSM network elements can be located anywhere within the IP "cloud," that is, they can be put where they best suit the requirements of the network. In other words, the traditional MSC/BSC architecture of legacy GSM networks is no longer a requirement. This means, for example, that an MSC can be located in one place, such as at a remote secure service provider facility, and the BSC/BTS infrastructure is only deployed as and where needed. Furthermore, call processing is distributed and intelligent. In a satellite example this allows local calls to connect locally (voice path requires no satellite bandwidth), and a mesh satellite network allows all long distance (over satellite) calls to be single hop.

- ***Network Expansion*** – An IP based soft switch makes service available anywhere within the IP network. New remote service areas can be easily added to the network regardless of location via satellite technology, and network expansion costs are incremental (i.e., a new service area does not require a new switch).

- ***Network Operations*** – Network operations can be simplified and reduced since the amount of remote infrastructure to be deployed is minimized, and key network infrastructure (e.g., MSC, billing, and other support functions) can be centrally located and leveraged to manage many remote areas.

- ***3G Ready*** – This solution is packet based and offers a clear path for 3rd Generation (3G) networks and services.

The key aspect of this solution is its highly distributed architecture. The use of a packet-based GSM switch allows for all the elements of the GSM network to interconnect via a packet (e.g., IP) network, and all elements therefore can make use of, and share, network resources regardless of their location. This allows for great economies of scale to be made in the deployment, management, and expansion of a network. It is noted this architecture won the GSM Association's 2003 award for best network architecture.

Figure 2 shows that a single Network Switching Subsystem (NSS) is deployed at a hub location. From this hub location IP communications links are established with the "Radio Access Networks" (RANs). This connection can be via leased line, fiber, cable, satellite, or other means. However in many cases it is common that the only reliable communication media between these areas and the hub location is via satellite. With this link in place, the NSS will process calls from, to and between the RANs. The NSS has intelligent call processing, meaning call signaling goes to the NSS, however the actual voice calls are directly routed to their destination. For example, a "local" call within a RAN is switched locally. The voice path does not traverse the NSS or make use of any IP backbone bandwidth. This results in a high quality, low latency call and is particularly important in limited bandwidth applications such as satellite.

A key advantage to note regarding this approach is the savings due to the sharing of common resources across multiple networks or RANs. The sharing is both in terms of infrastructure and operations. For example, a single centrally located NSS will support multiple RANs. It also allows for significant savings in operations in that a single centralized staff supports the multiple networks, thereby reducing the number of people and level of expertise required in the field.

It should be highlighted that the NSS can be located at an operator's switching center. Alternatively it can be located elsewhere within the IP cloud, such as at a teleport facility or telecom meeting house. This can be of particular advantage where the operator is offering service in rural and/or developing areas where there is typically limited qualified telecommunications resources available.

## 4.2 Network Optimization

There are many technical challenges involved with implementing a quality cellular phone system and integrating and aggregating other data services over satellite links in an IP infrastructure. Often good network optimization techniques become the deciding factor in an operator's ultimate success.

The key issues with respect to network optimization involve minimizing the effects of satellite delay, maximizing the utilization of satellite resources, and optimizing the differing and often conflicting requirements of multiple services and protocols which need to be integrated in concatenated networks. The best design for a particular network is determined by past experience, research, simulation, testing and monitoring.

Potential limitations associated with this architecture are based on the introduction of a fixed roundtrip satellite transmission delay of 500 milliseconds in the IP cloud, and the difference in error characteristics associated with satellite based transmission when compared to terrestrial based transmission systems normally assumed for the development of the protocols. Care must be taken to insure that each protocol can accommodate these differences. In order to reduce the effects introduced by the satellite delay, the network design must attempt to minimize the points or nodes where multiple exchanges in protocol handshaking would cause network bottlenecks, such as implementing techniques to reduce the number of signaling or control messages required in protocol exchanges. QOS techniques are also implemented to reliably handle the network traffic in an appropriate order of precedence (e.g., network signaling traffic is more important than an internet access request). Finally, optimum utilization of satellite resources requires a careful grooming of the protocols to assure optimum packet structure.

### 4.3 Network Tradeoff Example

As mentioned earlier, traditional GSM architectures have a number of limitations in satellite applications as a result of the combination of the centralized MSC/BSC functionality with the increased delay due to the satellite transmission path. A discussion of limitations and an example of cost/performance trade-offs is now given to provide comparison of a traditional GSM architecture with the IP softswitch architecture discussed.

The patent pending solution developed by Globecomm Systems Inc. and Telos Technology uses a softswitch in conjunction with GSM BSC and BTS subsystems. A packet network using Internet protocol created over a geo-stationary satellite handles the interconnection of these elements. This architecture is illustrated in the Figure 3 and dramatically reduces the complexity and cost of deploying remote GSM Radio Access Networks (RANs) over satellite. The traditional approach to deploying GSM over satellite has been to connect a handful of base stations to an existing BSC/MSC over a satellite link as illustrated in Figure 4.

Figure 4 shows how the traditional architecture uses satellite channels for the traffic, call setup, and Abis signaling. The softswitch architecture uses satellite channels only for the call setup. The table below summarizes the number of satellite voice channels required per type of call, as well as the delay introduced into the voice path for these calls. In addition the traditional architecture will introduce a 500ms delay in the Abis signaling impairing mobility performance.

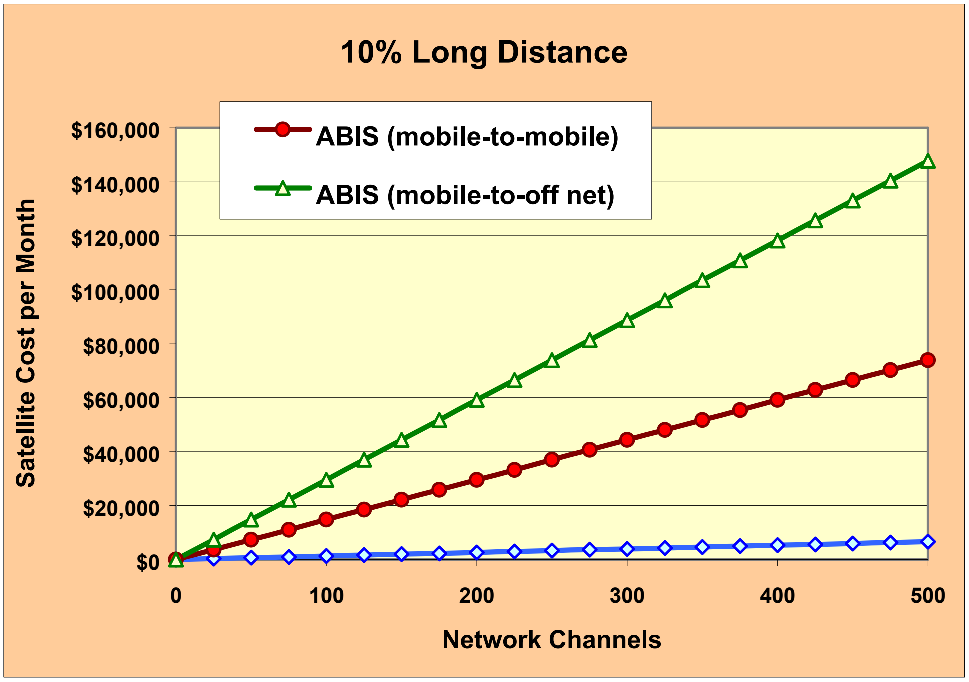
| Effects of Satellite Link | | |
|---|---|---|
| | **Softswitch Architecture** | **Traditional MSC** |
| **LOCAL CALLS** | | |
| Satellite channels per call | 0 | 4 |
| Satellite delay (round trip) | 0 ms | 1000 ms |
| | | |
| **LONG DISTANCE CALLS** | | |
| Satellite channels per call | 2 | 2 |
| Satellite delay (round trip) | 500 ms | 500 ms |

The table shows that the traditional architecture requires four (4) satellite voice channels, or two (2) full duplex satellite voice circuits, to complete a single local call (i.e., a call between two subscribers in the same local region), while the softswitch architecture requires none. This has significant impact on the amount of satellite bandwidth required for the network. This is a very important factor because satellite bandwidth is a recurring charge for operation of the network. Furthermore, all local calls suffer substantial delay due to the double satellite hop resulting in degraded voice quality.

The traditional MSC architecture has inherent impediments to growth of the remote radio access network as shown in the following example:

> In the traditional architecture we will require a duplex satellite channel for each end of the call. For a local call terminating on another network, this could mean two (2) duplex satellite channels for each mobile channel. For a network with 500 mobile radio channels and 10% long distance calling, we would require 450 satellite channels if all local calls are mobile to mobile on the network and 900 satellite channels to support the local calling terminating on another local network. Fifty (50) satellite channels are required to support the long distance calling. The softswitch architecture requires only the 50 channels for long distance calls.
>
> In terms of satellite bandwidth, each channel requires a minimum of two (2) 13.4 kbps of bandwidth on the satellite or 26.8 kbps per channel. The cost of this bandwidth for the two (2) extreme scenarios (all on net and all off net) is illustrated in the following chart (typical bandwidth costs have been assumed for the sake of this calculation). The actual cost will fall in the region between these extremes. The cost of the softswitch solution is shown as the bottom line in the chart and is largely insensitive to the number of network channels.

In addition, there would be an earth station hardware cost associated with the additional satellite capacity. One would need 10 to 20 times the power and bandwidth to support the traditional architecture.




**Monthly Satellite Cost as a Function GSM Radio Channels**

The bandwidth issue described above is a strong financial impediment to growing a remote RAN in a traditional network architecture. As mentioned earlier, voice quality is also an issue, and mobility performance (e.g., location updates, handover performance) will degrade as the RAN attempts to grow. This is because all mobile-BSC signaling incurs the satellite delay. This satellite delay is greater than the frequency of the updates between the mobile subscriber and the BSC. Therefore, it can be expected that handover performance will be poor in cases where a subscriber is mobile, and/or where the RAN consists of more than just a few base stations.

The general result of all these factors is that the remote RAN's performance and scalability is limited in a traditional GSM network architecture, and the distributed soft switch architecture described in this paper provides a major improvement in performance and reduction in cost of providing these services. In particular the softswitch approach is superior in terms of satellite bandwidth cost, delay characteristics in the voice channel, mobility (i.e., handover) performance, and call termination to wireline networks.

## 5.0 Conclusion

This paper has presented a discussion of the challenges and solutions now available to efficiently provide modern telecommunications services to previously disadvantaged areas. The solution is based on the integration of IP and satellite technologies. In particular it has been shown how these technologies can be coupled with IP softswitch technology to cost effectively provide multiple services, such as mobile telephony and broadband data, to geographically diverse and low density subscriber communities. Furthermore due to the large coverage area of the satellite's footprint, it is now possible to aggregate and manage these services for large geographic areas via a single common telecommunications infrastructure. This solution enables new economies of scale to be achieved for operators, such as those required to address the mandate of Universal Service.

# Figure 1 - Multi-Service IP Network

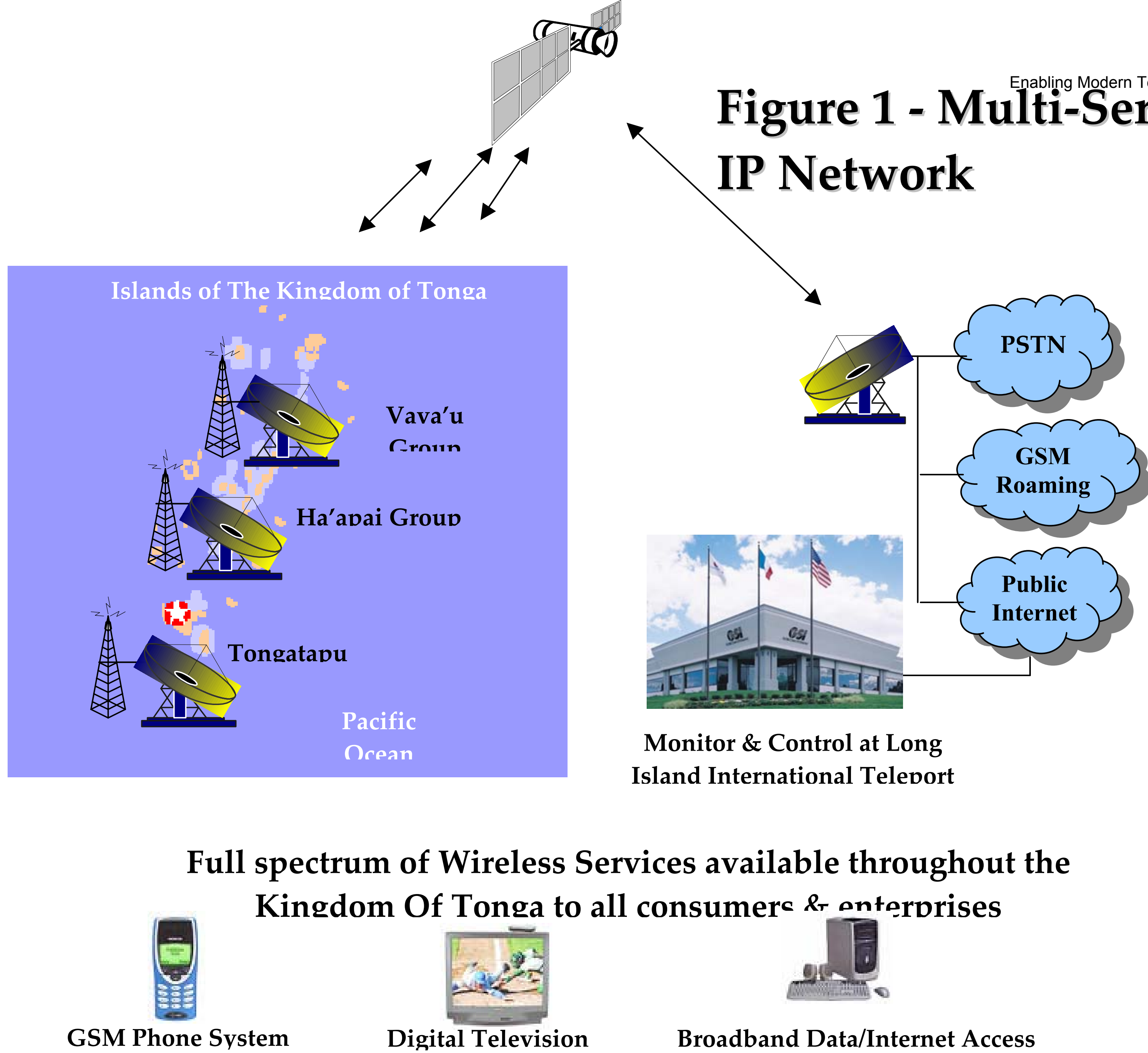
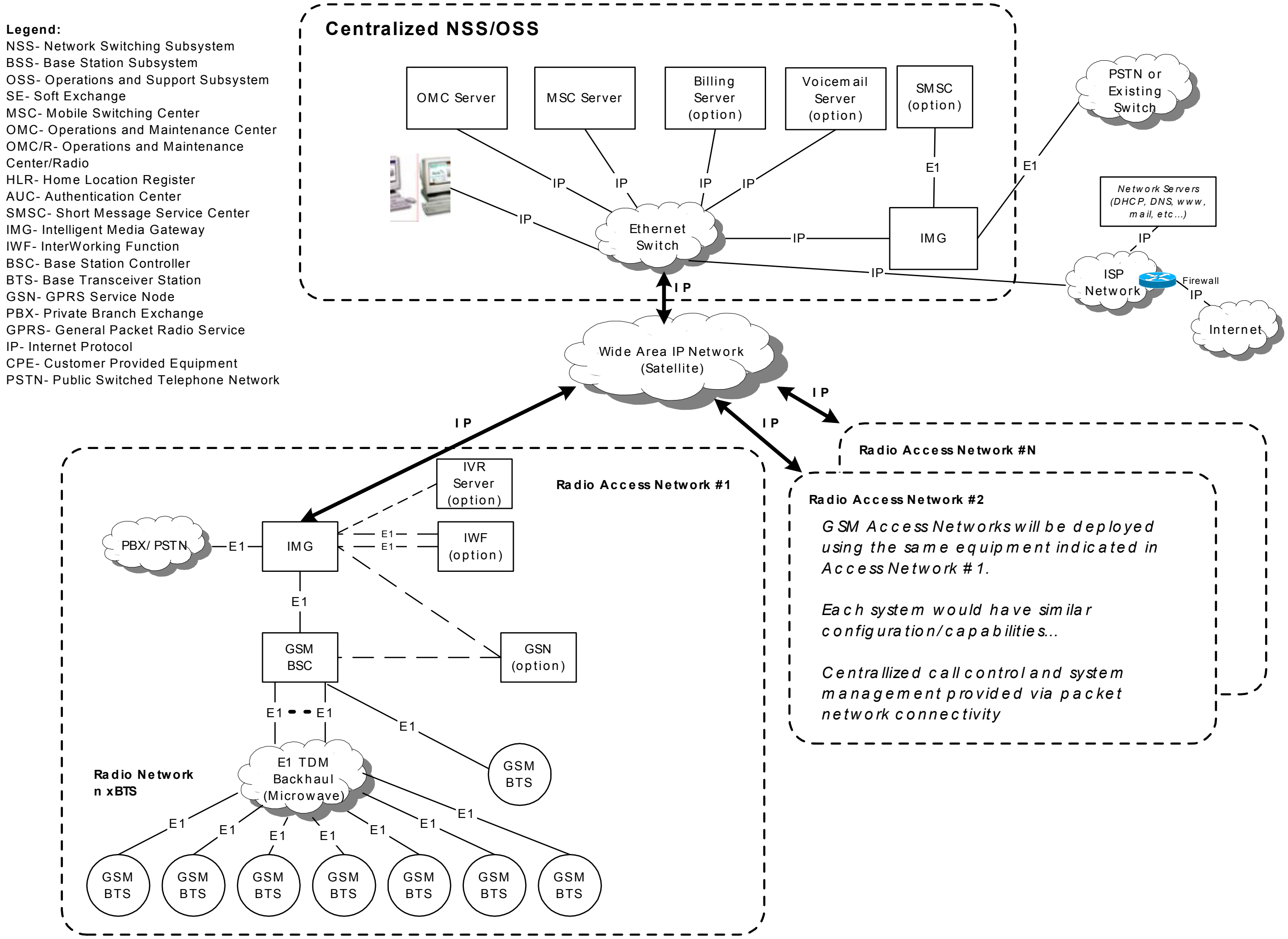


**Figure 2**
**Distributed GSM System**



**Traffic Channel Comparison**