Integrated Network Platform (INP) for Next Generation Networks (NGN)

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Abstract

The recent years have brought significant technological advances in the areas of palm-sized computers and wireless communications, accompanied by an infiltration of the Internet in all aspects of our lives. Mobile Internet access accounts today for only a tiny proportion of the Internet users. However, it is forecasted that as early as 2003 almost half of the Internet population will consist of mobile access devices [1]. By that time, a variety of different wireless network platforms with different properties, capable of transporting Internet traffic will be available. Consequently, a technology that allows the integration of heterogeneous networks into a single platform capable of supporting user roaming between them, while not interrupting active communications, will gain importance. This development will be assisted by the rise of new mobile devices capable of "understanding" and using various network platform protocols. In addition, the turn of operators towards the license-free frequencies and their eventual congestion will lead to the realisation of alternative dynamic network structures, namely IP-compatible, multi-hop, ad-hoc networks.

1. Introduction

There is currently a large variety of heterogeneous (incompatible) network platforms available, capable of providing data services. However, such systems require that users remain connected to a single platform or terminate all communications when changing. The key enabling technology that will form the basis of integrated network platforms is the Internet Protocol and its extensions. The most important extensions with respect to this document are the Mobile IP protocol from the IETF group for IP Routing for Wireless/Mobile Hosts (mobileip[2]) and the up-coming standard from the Mobile Ad-hoc networks (manet[3]) working group. Mobile IP is considered as the technology that will allow for the integration between all wireless as well as wire lined network platforms. Moreover, Ad-hoc networks are considered as an integral part of such networks with a prominent position.

Integrated network platforms have numerous advantages:

- **True global roaming:** Mobile IP enables roaming between all technologies that support IP services, while not interrupting active communications. Consequently, a user could always remain connected by utilising whatever technology is available at the moment. Moreover, in the complete absence of infrastructure users could establish a dynamic ad-hoc network organisation that spans to the boundaries of the infrastructure and provides connectivity to all.
- **Integration of services:** The services that can be provided over the Internet Protocol no longer focus solely on data services rather have been extended towards telecommunication services. Through an all IP infrastructure it is possible to provide the integration of the two in a seamless manner through a single device.
- **Platform selection depending on network properties:** The variety of possible underlying technologies will enable devices to transparently select between them, with respect to the requirements of the active communications, i.e. a Wireless LAN that provides higher bandwidth capacity might be more attractive for rich content services than UMTS.

2. Integrated Network Platforms through IP

The Internet Protocol was originally designed to interconnect heterogeneous wirelined networks. This property of IP to integrate, is inherited by its Mobile IP [4] (MIP) extension that focuses on mobile environments. Originally MIP was designed as a solution to the problem of node portability. However, further extensions to MIP and existing research [5] have indicated that MIP can also provide mobility support. As a result, the key enabling technology that will form the basis of Integrated Network Platforms is the Internet Protocol and its extensions.

The lack of considerations for mobility management in the original Internet Protocol design indicate that a mobile node would be reachable only as long as it remained within the boundaries of a given IP administrative domain (IP network). Should a mobile node change its point of attachment to another IP network, it would remain unreachable by all communication peers until it returned to its home environment. This is considered as a significant restriction because it forces users to remain under the influence of a single service provider or network technology (i.e. GSM) in spite of utilising mobile or portable devices. Moreover, the availability of wireless and wire-lined communication mediums will continue to increase accompanied by a plethora of access devices. In addition, the turn of operators towards license-free frequencies [6] and their eventual congestion will lead to the realisation of alternative dynamic based on the common convention that users may utilise one another's resources to mutually form a dynamic network structure. This solution poses as a low-cost, high-complexity alternative to conventional systems that will dictate a significant shift in complexity towards the end devices. This will give rise to a new generation of access devices with several access interfaces that will allow simultaneous connectivity over a range of providers and technologies.

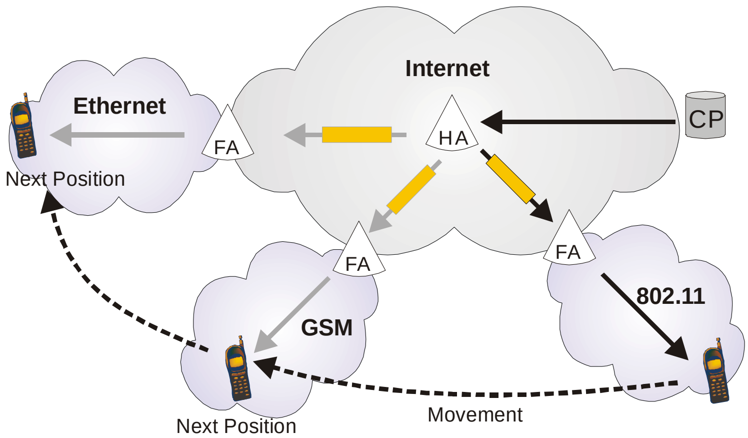

Figure 1 Mobile IP

In this environment of multiple providers and access media, a technology that allows the integration of IP capable networks technologies into a single platform capable of supporting user roaming between them will gain importance. Moreover, the wide range of access devices will dictate the de-coupling of users from the mobile phone or personal computer. In that case, users will be able to change between devices, even while communicating, without interrupting their communications. This will enable users to take advantage of the full capacity of each access device in order to communicate more efficiently and in a manner that matches their own requirements. Moreover, it will provide the means for remaining always reachable as any available communications device in the vicinity of the user could be deployed to perform personal communications without further customisation. However, the original Internet Protocol design did not include any considerations for such services. That is, the Internet Protocol did not allow any user roaming between IP networks, let alone switching between devices while communicating. As such, any of the described cases would cause a violent break of all active communications.

A solution to the problem of Internet mobility management can be provided through Mobile IP. Mobile IP [7] is an extension of the basic Internet Protocol design that enables mobile node roaming between IP networks without having to interrupt established communications while remaining reachable on a permanently allocated IP address. As an extension of IP, Mobile IP inherits the ability to interconnect homogeneous as well as heterogeneous network technologies (i.e. HiperLAN2 and UMTS). As such, mobile nodes may roam between a variety of IP capable wireless and wire-lined technologies while initiating data as well as telecommunications through a single device. In this manner, the problem of integrating heterogeneous network technologies is reduced into a matter of network layer routing. However, Mobile IP does not go far enough in order to provide the facilities for the handling of communications on a per flow basis. Mobile IP provides a mobility management solution for the total of a mobile node's received and transmitted traffic but does not provide the capacity to define mobility management behaviour for individual traffic types. That is, given multiple access interfaces, a mobile node might choose to perform multimedia services over a high-cost, high-bandwidth network, while other services could be run over an ad hoc segment with no cost but best effort behaviour.

3. Integrated Network Scenario

The typical integrated networks scenario is envisioned as follows. Ideally in all indoor locations it will be possible to deploy a Wireless LAN infrastructure. As such a mobile user coming out of an airport and into a taxi, to his hotel and any travel destination will be able to take advantage of this low-cost high-bandwidth platform. Between locations, the mobile equipment (WLAN-enabled laptop / palmtop) will use the service offered by a local cellular provider (GPRS, UMTS). In areas where infrastructure in not present or those with high user concentration, travellers may attempt to participate in a multi-hop ad hoc network. This will enable for very low cost, high data rate service. Mobile IP will play an important role in gapping heterogeneous technologies and mobility between Internet administrative domains.

Interworking of the WLAN technologies with cellular infrastructures is a hot topic, which has been addressed within the context of NGNI-SMONET. That is, new rules need to be developed that should determine when a terminal wishes to initiate a move between administrative domains. Moreover, it needs to be determined what the impact of such a change will be given that each of those technologies provides different service characteristics and can support different QoS requirements. That is, mobility from a high data rate WLAN network into a GPRS network will be accompanied by a dramatic degradation in the available data rate. Moreover, NGNI-SMONET has gone one step further and investigated multi-hop, Internet compatible, Ad-hoc networks based on Wireless LAN technology as an alternative platform for the delivery of the NGNI-SMONET services.

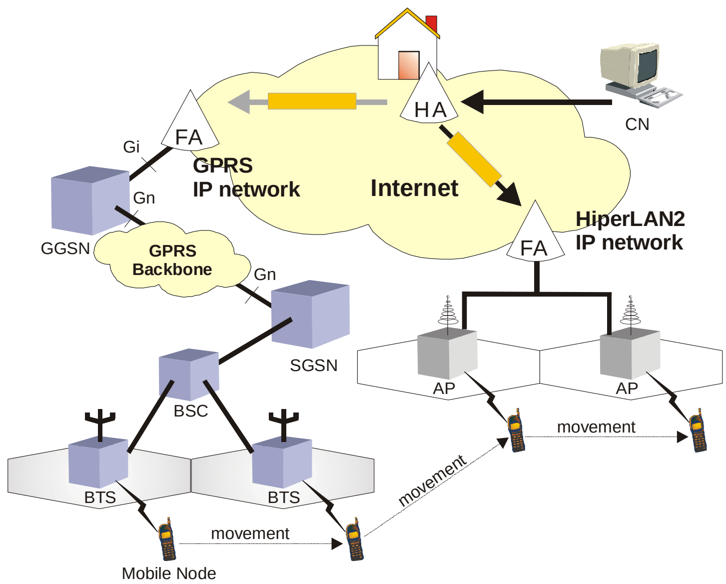

Figure 2 Integrated GPRS, HiperLAN2 Platform

For the issue of switching between devices while communicating, Mobile IP could be used in order to maintain a single point of attachment to the Internet after a switch between access devices has been undertaken. However, further changes are required that involve: issuing a new process on the new device capable of undertaking the communication; transferring the state of the communication from the previous to the new device; adapt the communication at both ends and adapt the content to match the capabilities of the new device. That is, transferring a communication between a television and a mobile phone, as the user is leaving its house, might require the renegotiation of the content format as the new device might be unable to maintain the service provided by the previous one.

4. Mobile Ad-hoc Routing

Mobile ad-hoc routing protocols allow nodes with wireless adaptors to communicate with one an-other without any pre-existing network infrastructure. Existing ad-hoc routing protocols, while robust to rapidly changing network topology, assume the presence of a connected path from source to destination. Given power limitations, the advent of short-range wireless networks, and the wide physical conditions over which ad-hoc networks must be deployed, in some scenarios it is likely that this assumption is invalid. There is a need, that messages will deliver in the case where there is never a connected path from source to destination or when a network partition exists at the time a message is originated.

The advent of inexpensive wireless networking solutions has enabled a broad range of exciting new applications. Wireless network adaptors in portable computing devices, such as cellular phones, personal digital assistants, and laptops, can enable ubiquitous access to global information resources. Challenges to achieving this vision include the need to have a wired base station in range of wireless hosts and the energy/expense of transmitting information across large distances. Ad hoc wireless networking addresses some of these challenges by allowing mobile hosts to communicate with one another with no pre-existing communication infrastructure. In ad hoc networks, arbitrary mobile hosts can be recruited to “fill the gap” by serving as intermediate routers between two hosts that may otherwise not be in direct transmission range of one another. Recent work investigates route discovery and maintenance, minimizing power consumption [8], and maintaining QoS guarantees in ad hoc networks.

The common assumption behind existing ad hoc routing techniques is that there is always a connected path from source to destination. However, the advent of short-range wireless communication environments (e.g., Bluetooth) and the wide physical range and circumstances over which such networks are deployed means that this assumption is not always valid in realistic scenarios. Unfortunately, with current ad hoc routing protocols, packets are not delivered if a network partition exists between the source and the destination when a message is originated. Certain applications, such as real-time, constant bit rate communication may require a connected path for meaningful communication. However, a number of other application classes benefit from the eventual and timely delivery of messages, especially in the case where frequent and numerous network partitions would prevent messages from ever being delivered end to end.

In the context of such applications, the goal of this work is to develop techniques for delivering application data with high probability even when there is never a fully connected path between source and destination. Thus, our work makes minimal assumptions about the connectivity of the underlying ad hoc network:

- the sender is never in range of any base stations,
- the sender does not know where the receiver is currently located or the best “route” to follow,
- the receiver may also be a roaming wireless host, and
- pairs of hosts (not necessarily the sender and receiver) periodically and randomly come into communication range of one another through node mobility.

One approach, called Epidemic Routing is to distribute application messages to hosts, called carriers, within connected portions of ad hoc networks. In this way, messages are quickly distributed through connected portions of the network. Epidemic Routing then relies upon carriers coming into contact with another connected portion of the network through node mobility. At this point, the message spreads to an additional island of nodes. Through such transitive transmission of data, messages have a high probability of eventually reaching their destination.

The overall goal of Epidemic Routing is to maximize message delivery rate and minimize message delivery latency, while also minimizing the aggregate system resources consumed in message delivery. This can be reached by placing an upper bound on message hop count and per-node buffer space (the amount of memory devoted to carrying other host’s messages). By increasing bounds on these parameters, applications can increase the probability that a message will be successfully delivered in exchange for higher aggregate resource consumption.

The goals of Epidemic Routing are to:

a.) Efficiently distribute messages through partially connected ad hoc networks in a probabilistic fashion,

b.) Minimize the amount of resources consumed in delivering any single message, and
c.) Maximize the percentage of messages that are eventually delivered to their destination.

Epidemic Routing raises a number of interesting issues for the underlying routing protocol: [9]

- **Routing Under Uncertainty:** Message senders have inexact knowledge of the location of nodes through-out the system. Thus, a key issue is determining whether to transmit a message when a host comes into range of a potential carrier. For example, the system may account for the hosts that the target carrier has recently come into contact with and its current destination/velocity.
- **Resource Allocation:** Unlike standard routing, it is likely and perhaps even desirable to have multiple copies of a message in transit simultaneously. In general, the system must balance the conflicting goals of maximizing message delivery and minimizing resource consumption. For example, a single message should not consume buffer space at all the hosts in the Internet just to ensure its most timely delivery. On the other hand, copies of a message may be buffered at multiple hosts to maximize the likelihood that a particular message is eventually delivered.
- **Performance:** A given message exchange and routing protocol can be evaluated along a number of different axes. Performance metrics include the average latency in delivering messages, the average amount of system storage and communication bandwidth consumed in delivering a message, and the amount of energy consumed in transmitting the message to its destination. This last metric of energy consumption is particularly relevant to mobile hosts because a host must consider the energy con-sequences of becoming a carrier for a particular message. Since storing and transmitting messages consumes energy as well as traditional performance metrics such as CPU cycles, memory, and network bandwidth, it is important to balance the consumption of all system resources in transmitting messages to their final destination.
- **Reliability:** Given the probabilistic delivery of messages in our model, certain applications may desire acknowledgments of successful message delivery. For example, the originating host and all carriers can free up resources associated with a message upon learning of its successful reception at the intended host.
- **Security:** A message may traverse an arbitrary path of hosts before reaching its ultimate destination. Depending on the sensitivity of the information and the requirements of individual applications, receivers may require certain guarantees about the authenticity of a message. While well-known cryptographic techniques can provide some such guarantees, it may also be beneficial to track the entire path that a message travels in reaching the receiver. In this way, receivers can learn if a message has been exposed (even in encrypted format) to untrusted hosts. Similarly, carriers can use the sensitivity information associated with a particular message to eliminate untrusted hosts from the list of potential carriers.

5. Roaming between different networks

The roaming between the different mobile technologies (e.g. WLAN and UMTS) has not developed. A need is cutting-edge software that enables greater mobility and productivity by enabling secure and seamless communication with the Internet and other networked computers from the WLAN environment as a starting point.

One example for a roaming between different WLAN access points is here available, which could enable roaming with automated access point detection and configuration. This possibility offers complete seamless connectivity between different WLAN environments. This allows the ability to locate and connect to different access points and automatically configure the TCP/IP settings, in conjunction with the ease of installation and configuration.

Current wireless LAN environments operate somewhat independently, each with its own configuration. Although the IEEE802.11b standard allows for roaming between access points, the standard does not address the complexities of the wired infrastructure. A possible solution has to bridge the gap between wireless roaming and wired network diversity. This permits users to travel between and amongst different wireless environments without the traditionally complex configuration that is required each time the user moves between network environments.

During installation, the wireless configuration and TCP/IP settings have to automatically set. In addition, connectivity should be established in infrastructure and as ad-hoc mode; as well as DHCP and static IP network environments. As laptops and other wireless devices become less expensive and more available, they are increasingly utilised in varying business applications. Businesses are now depending on these devices to facilitate communication and increase productivity. Using notebooks and hand-held devices allow employees to be mobile and more productive. In the past, mobility between both wired and wireless networks has been constrained by the complexities of subnet-dependent network configurations. The wireless network has to facilitate mobility and productivity by allowing users to easily discover access points and establish a wireless network connection.

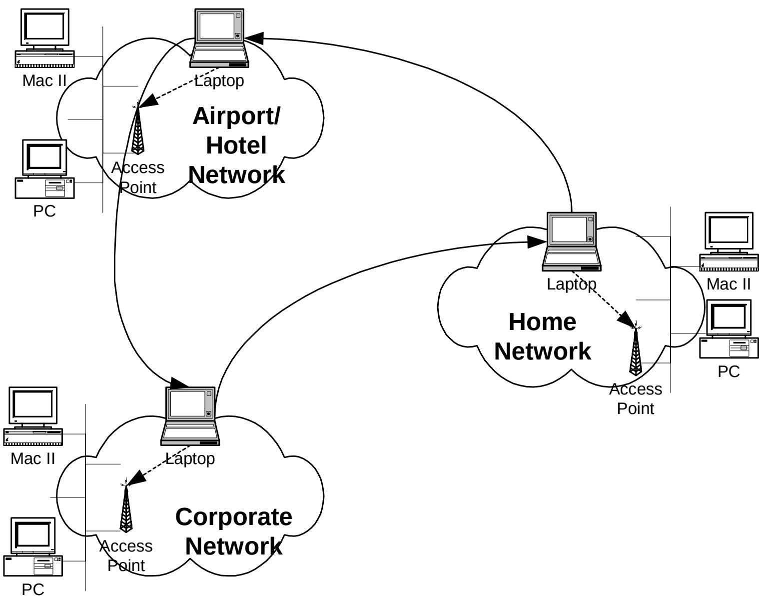

Figure 3 Roam freely in wireless network environments

The following features should be integrated in such a solution: [10]

- **Simple, Convenient Installation:** The wireless network should provide default setting selection during installation. When combined with clean install and uninstall processes with minimal reboot and silent option, deploying a wireless LAN becomes routine.
- **Automatic Network Discovery:** By automatically scanning, the WLAN should discover all wireless networks within range of the laptop.
- **Dynamic Access Point Switching:** Dynamically or manually switch to any access point that has been set up in a user's profile. At the same time, let the WLAN dynamically change the wireless configuration and TCP/IP settings without rebooting.
- **DHCP and Static IP Network Support:** The WLAN should support quick, seamless switching between DHCP and static IP networks without user intervention.
- **Infrastructure and Ad Hoc Configuration Support:** The WLAN should support dynamic switching between infrastructure and ad-hoc wireless environments.
- **Wireless Diagnosis:** The software should enable users to determine when there are problems or inconsistencies with the current networking parameters.
- **Increased Productivity**: The 802.11b WLAN users will be more productive as they are able to roam freely in multiple work environments and at home while staying connected.
- **Decrease Deployment Costs**: The cut down on management of 802.11b WLANs with auto-configuration of required parameters and auto-access point scanning.
- **Simplify Configuration:** sets the required parameters during installation and lets users select from the available access points.
- **Secure Your Network:** Secure the WLAN with built-in wired equivalent privacy (WEP) communication between the laptops and access point.

In today's demanding and flexible work environment, laptop connectivity is essential at work and at home. Therefore, there is a demand for easily stay connected in both locations. In traditional WLAN enterprise environments, professionals are limited to their immediate work area because both wireless settings and TCP/IP changes are required to maintain connectivity. A solution must allow professionals to move between an enterprise and home network without reconfiguring the network settings or rebooting. The system must automatically recognise and connects to the correct wireless access point at home or at work.

6. Conclusions

Interworking of the WLAN technologies with cellular infrastructures is a hot topic, which will be addressed within the context of the IST project NGNI within its activity SMONET (http://www.decoit.de/smonet/). That is, new rules need to be developed that should determine when a terminal wishes to initiate a move between administrative domains. Moreover, it needs to be determined what the impact of such a change will be given that each of those technologies provides different service characteristics and can support different QoS requirements. That is, mobility from a high data rate WLAN network into a GPRS network will be accompanied by a dramatic degradation in the available data rate. Moreover, NGNI-SMONET will go one step further and investigate multi-hop, Internet compatible, ad hoc networks based on Wireless LAN technology as an alternative platform for the delivery of the NGN services.

The extended full paper version will describe in detail, how the interoperability between the different networks like WLAN, Ad-hoc networks, and GPRS could work. Additionally routing, roaming, and service discovery will be explained.

7. Acknowledgements

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