"UniDirectional Link Routing protocol"

Introducing the benefits of an open IP standard for asymmetric routing, providing transparent interactive return channels in multicast networks

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Executive summary

This paper introduces Uni-Directional Link Routing (UDLR) technology, a routing protocol recently ratified by the IETF.

Chapter 1 presents the market issues leading to convergence currently occurring at the edge of both broadcast and telecoms worlds, spurred by current Internet growth and the wide adoption of the Internet protocol (IP).

Chapter 2 provides a preliminary overview of UDLR technology, why it has been developed and what its principal benefits are.

Chapter 3 outlines the functionality which is enabled by the UDLR technology in order to fully exploit the benefits of the convergence between broadcast and telecoms networks, focusing in particular on the financial and operational issues.

In Chapter 4, examples are given of typical applications that can take advantage of such technological building blocks. A layered approach is proposed to distinguish between access services, content distribution services, and the "ultimate" end user application services, that may be supported through different networking technologies such as JAVA and .NET.

To conclude, a vision of the continued direction of convergence is presented in Chapter 5.

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1 Introduction

1.1 Candidate networks for carrying IP data

Today, the Internet protocol is widely used to deliver interactive content to a wide range of business and consumer audiences. The Internet itself has been considered as the convergent medium for delivering all types of content, due to its pervasive reach. However, the “over hyped” visions of next-generation Internet applications have not yet come to fruition.

For example, the dream of providing TV quality content over the Internet has yet to happen, due to the significant costs of using a network primarily designed for point-point-point communications to reach large audiences. In enterprise networks, the advent of rich applications such as e-learning and video conferencing have had very slow growth. Pioneering web-casters such Victoria's Secret or the NetAid concert in 1999, have experienced the infamous ‘success penalty’ due to the linearly rising costs per viewer of IP uni-casted content.

These problems are in part due to the very fact of IP’s ubiquitous connectivity, which comes at a price of performance. It is only in the last few years that IP technology development has tackled the bandwidth capacity issue head on (with the rise of Content Distribution Networks, and video streaming solutions). Two aspects of current Internet traffic present ironic contrasts to the way that the Internet was originally conceived – approximately 30% of Internet traffic is multicast in nature, and the highest-growth applications have asymmetric traffic flows (much heavier forward than return traffic)[1].

In contrast, networks conceived from the very beginning to carry rich media economically to large audiences are the traditional radio and TV networks. Broadcast TV networks can scale infinitely based on the existing infrastructure, as demonstrated by the last soccer World Cup final match reaching over 1 billion screens – the equivalent of over 2,000 times the Internet’s long haul transit video streaming capacity[2]. In particular, the success of satellite TV is undisputed, demonstrating efficiencies in reach and number of channels.

A combination of these two technologies could achieve the vision of truly affordable rich media transmission. The interactivity provided by the IP networks, could provide localisation and personalisation functionalities, all based on open standards for flexibility and lowest costs.

The bridge between these mediums is being built in the form of new standards such as DxB, used for digital TV (DVB) and digital radio (DAB). These protocols are able to carry data and, in particular, IP packets. They are usually considered as broadband (up to typically 40 Mbps for DVB-S (satellite) and cover large areas (typical satellite footprints have continental reach). They can also provide a high quality of service without perceptible bottlenecks.

The expanding terrestrial networks are complementary to broadcast channels. Being almost all unicast based (point to point), and of low to medium bandwidth (below 1 Mbps), the terrestrial channels are now able to play a key role in establishing an interactive return channel, creating a hybrid network. The hybrid network perfectly exploits the strengths of both channels – broadcast scaleability for the forward channel (downlink), combined with the ease of access to Internet connectivity via a PSTN[3] line on the return channel (uplink). Due to the aforementioned asymmetric nature of much Internet traffic, a user whose uplink may remain ‘narrowband’ does is not prevented from exploiting next generation broadband services and applications.

A hybrid network has two equal roles to play in both the enterprise and mass consumer markets. The first is to reduce bandwidth costs, providing a compelling return on investment argument. The second is to enable new content to be delivered to new customers, generating new revenue streams for those businesses that do not intend to rely on their traditional product lines.

[1] An example is the asymmetric traffic patterns of online gaming, which represents half of South Korea’s traffic (the country which has by far the world’s highest broadband penetration).
[2] Based on long haul transit capacity of 150Gbps, only being able to carry 500,000 viewers of a television channel encoded at 300kbps.
[3] Public Switched Telephone Network

1.2 The Origin of UDLR

UDLR was developed to combine the best of both Worlds using today's most versatile network protocol - IP. It was clear that in order to enable multicast content to become interactive, a standard protocol for the back channel was required.

To date, this issue has been tackled by existing technology players with proprietary, closed solutions. Inherently therefore these solutions are limited in their compatibility with other platforms, applications and equipment – which increases costs and complicates future evolution.

Asymmetric routing, relating specifically to the interactive return channel, has been studied within the IETF (Internet Engineering Task Force - standardisation & regulatory body for Internet activities), within the UniDirectional Link Routing working group (UDLR). The result of this work has been the design of a mediation layer between the broadcast and interactive medium on one side, and the IP layer on the other. This mediation layer is explained in more detail in Chapter 2, where an insight into how UDLR provides standardized back channel interactivity is provided.

2 How UDLR standardizes asymmetric channel routing, and the use of a return channel

2.1 UDLR as a mediation layer

Integrating broadcast links in the Internet is not a trivial task because most of the protocols used in the Internet assume that the connection medium is bi-directional. INRIA, the French Institute for Automation and Information technology, tackled the problem.

1. At first, draft solutions attempted to adapt existing Internet routing protocols such as RIP and OSPF so that they could operate on such links. This was in fact an inefficient approach as it implied rewriting all the routing protocols and destroying 20 years of Internet development…
2. Rapidly, researchers involved in this process decided that the best way was to make the link "bi-directional" from a link layer standpoint, in order to keep all Internet applications and protocols unchanged.

The UDLR working group came to the conclusion that there is a need for a mediation layer between the lower physical communication layers and the IP layer. The principle of this mediation layer is detailed in Figure 1. Depicted is a satellite terminal receiving a data feed on a DVB card. The application protocol receives the IP packets and, when trying to answer, sends the packets via the satellite interface. Due to equipment and bandwidth costs, the satellite DVB cards are typically receive-only devices). The aim of the UDLR layer is to intercept the packets going to the DVB card and send them on a terrestrial bi-directional interface, such as a GSM or PSTN connection.

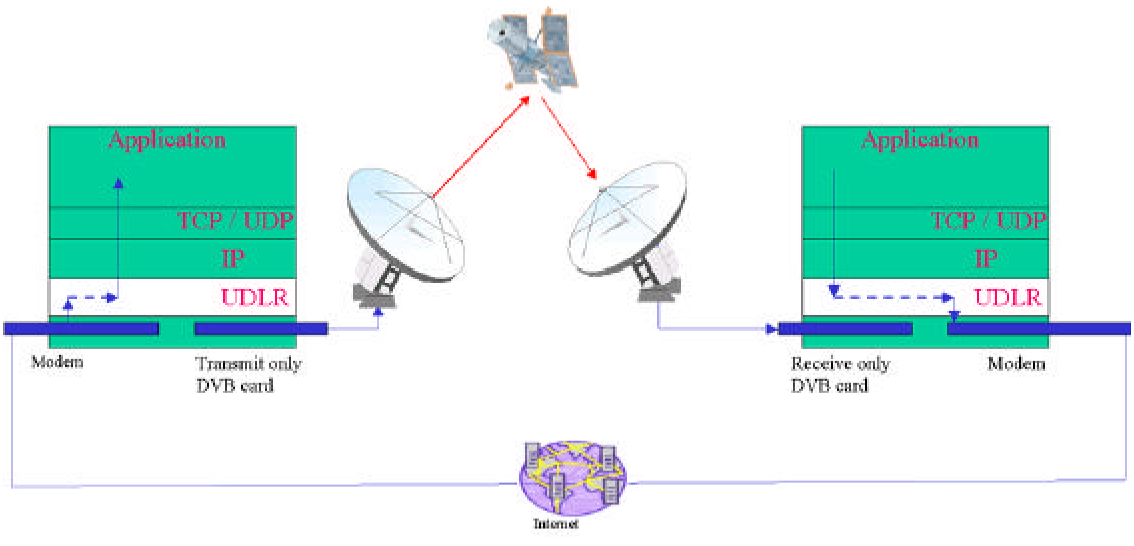

Figure 1 : UDLR as a mediation layer

In Figure 1, UDLR is shown to act as a mediation layer between the IP layer and the lower physical asymmetrical layer. Packets are intercepted on the return link at the UDLR layer before being encapsulated in a

GRE tunnel [1] and sent via the Internet to the feed without changing the content payload. The feed in turn decapsulates the packets as if they were coming from the satellite itself.

2.2 Resulting topology

The reception interface using the UDLR protocol, behaves as if it was a normal bi-directional interface, receiving and sending data. All senders and receivers on satellite broadcast links therefore behave as though they were connected to the same shared LAN such as an Ethernet LAN. Subsequently, all applications, transport and network protocols that work on a LAN, will work unchanged. This is illustrated in Figure 2.

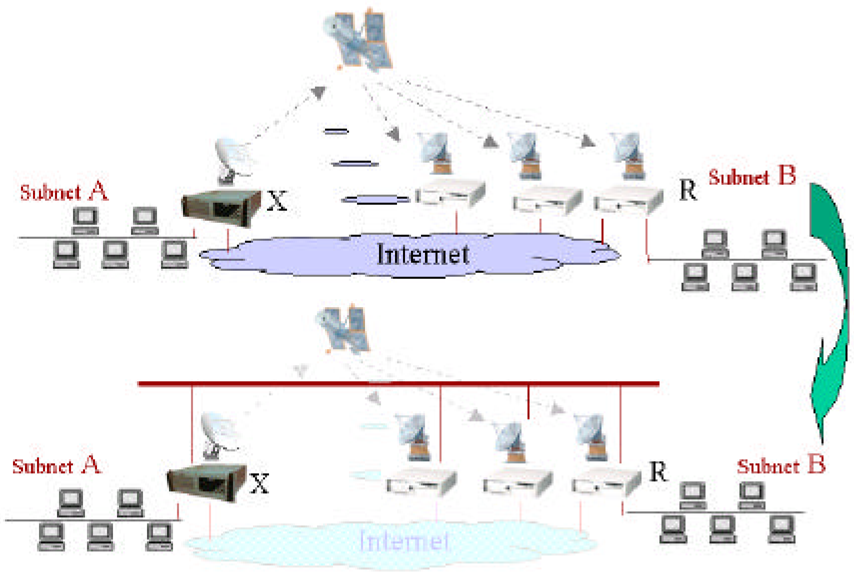

Figure 2 : resulting topology due to UDLR

2.3 UDLR, the newly-defined Internet standard

At an early stage of the study, the INRIA research centre with the collaboration of Hitachi, Sony, Jsat, etc… proposed the creation of a UDLR Working Group to the IETF (Internet Engineering Task Force). The IETF is an international organization, composed of researchers from academia and from private companies, where new Internet protocols are defined. (www.ietf.org). The UDLR working group was created in the Routing Area. This group subsequently authored an Internet Draft, which was entered into the Internet Standard Track. UDLR is now an Internet proposed standard [2] since March 2001. Various UDLR implementations are now available in Japan, the USA, and France, and interoperability tests have been completed successfully.

UDLR is now recognised as one of the most important building blocks for enabling convergence between broadcasting and telcoms worlds through the IP protocol. The early adopters include Alcatel Space, Hitachi, I-Pricot, Sony, Thales Multimedia (Thomcast) and UDcast.

3 Added optimisation

Once we have full bi-directional connectivity between the feed and the receivers using a return channel, we find that there are several issues to be tackled in order to propose a *cost effective* and *operational* system. Indeed, emulating a small simple Ethernet LAN is often not enough. To meet the requirements of a continental and asymmetric LAN, the following issues must be addressed:

- Bandwidth optimisation, for the broadcast and the return links
- Scalability
- Security
- Administration

3.1 Broadcast link optimisation

Broadcast channels are usually very expensive and each bit must be spared. The optimisation can be done at different layers but the overall objective is to provide support for IP multicast services optimised in flat broadcast networks. Contrary to perceived limitations, multicast can indeed be enabled for “pay once and bill many times” functionality, and is therefore a natural fit for broadcast links.

1. *Layer 1*: Optimisation can be performed on the waveform to improve spectrum use and bit/Hz efficiency. Current research is investigating 8PSK/TCM modulation as well as improved coding (turbo decoding);
2. *Layer 2*: Optimisation can be performed at the MPEG layer or the Ethernet layers, the idea being to remove idle cells as much as possible, especially when multiplexing IP traffic with video/audio traffic (statistical multiplexing);
3. *Layer 3*: There are several possible solutions for supporting IP multicast routing - sparse, dense and now in source specific modes. In UDcast’s configuration, flat networks are emulated as local area networks, in which case dense mode becomes the most suitable multicast mode.
4. *Layer 4*: Adaptive FEC (Forward Error Correction) is an important functionality to ensure the integrity of the data, dynamically taking into account the actual transmission conditions. Usually packet error protection is designed to fit to worst case conditions (largest FEC). With the use of the interactive link, it is possible to adapt the FEC to follow real conditions and hence save bandwidth. Another way to optimise the use of the return link is to carefully tune the protocols to take into account the relatively high round trip time found in satellite-based networks.
5. *Higher layers*: The interactive-multicast architecture as described above, suits very well applications such as streaming, distributed processing, newsgroup updating, intranet broadcasting, and the JAVA network toolbox.

3.2 Interactive link optimisation

The uplink is often low bit-rate, based on volume or time based billing, as is the case for both fixed networks (such as PSTN/ISDN) and for mobile networks (such as GPRS/UMTS). As a consequence, solutions need to optimise the utilisation of the uplin k as best possible, in particular establishing the connection “on demand”.

Additionally, the use of the return channel can be optimised by trying to limit the number of control messages returned on the uplink. These optimisations are closely linked with the anti-feedback implosion mechanism explained in paragraph 3.3. Finally, particular attention should be paid to the optimisation of the management of acknowledgements on the uplinks. Protocols such as TCP are known to acknowledge every received packet, inducing large amounts of transferred and redundant data on the uplink, especially when reception capacity is at broadband rates (asymmetric to the uplink).

It is important to take notice of the possibility to use protocols in an optimised way, reducing the need to resort to the use of the interactive uplink. In certain cases, it may not be necessary to use the return channel immediately (in the case of content ‘push’), however it may be used as an option for future use for reconfiguration, extension of functionality etc.

3.3 Scalability

One of the most important constraints is to make the network scalable, in order to be able to serve potentially millions of terminals. One of the possible solutions is to limit control messages to the maximum in order to avoid congestion on both the network side and the server side. One of the most critical issues is feedback implosion: all protocol mechanism that would result in having a data source receive tens of thousands of feedback messages from receivers must be avoided. Scalability should enable any operator to host an increasing number of terminals, without any impact on the network architecture, nor on the server capacity.

3.4 Security

The broadcast system must be secure as it is wireless based. Wireless systems are often considered only mildly secured as eavesdropping is relatively easy. In the case of UDLR, there is also a special need for authenticating users in order to grant access to the uplink resource. Security can apply to both the content and the connectivity access.

3.5 Administration

Finally the system must be easily administrated. Administration must be tailored for large-scale networks that might encompass hundreds of thousands of users. For instance, it should be easy to configure a large number of terminals simultaneously through both practical and efficient means. It should also be possible to take control of "rogue" terminals that have lost their configuration and cannot, for instance, receive data on the broadcast link. The need to remotely administrate the network is made particularly acute with the frequently unbalanced IP system intelligence between the feed and the receiver terminal.

4 Applications

With the previous requirements addressed, a number of highly interesting applications can then be deployed in a very efficient manner over broadcast links. These applications have been categorized in different generic layers in Figure 3:

- *Access layers*: This layer includes applications related to connectivity, either for internet broadband access, private network access, or even to mobile networks; typical examples include providing xDSL connectivity to remote areas, or connecting retail outlets directly to the head office's LAN.
- *Content distribution layer*: This layer includes all the content delivery technologies such as streaming, caching and peer to peer.
- *Application layer*: Correspondes to the traditional application layer, which can be built using JAVA or .NET technologies. Potential applications include transactions, video conferencing, ERM/CRM and many others.

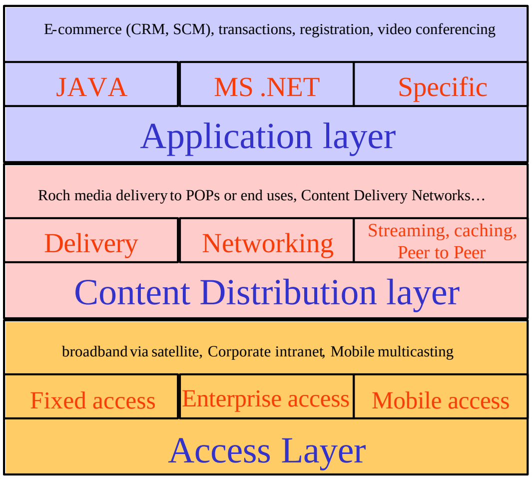

Figure 3 : classification of relevant applications to UDLR technology

4.1 Access layer

4.1.1 Fixes broadband access

UDLR is today the favoured solution to bring xDSL-like connectivity to areas where copper-based xDSL will never be deployed because of the large distance to the nearest exchange. For instance, France Telecom R&D has validated the use of UDLR for such types of services with a "commoditized" return link that may be either terrestrial or satellite [3]. The use of UDLR is privileged here as it efficiently supports Ethernet and thus PPP over Ethernet. PPP over Ethernet is currently used for connecting an xDSL modem to a broadband access server (BAS). The proposed architecture is as follows:

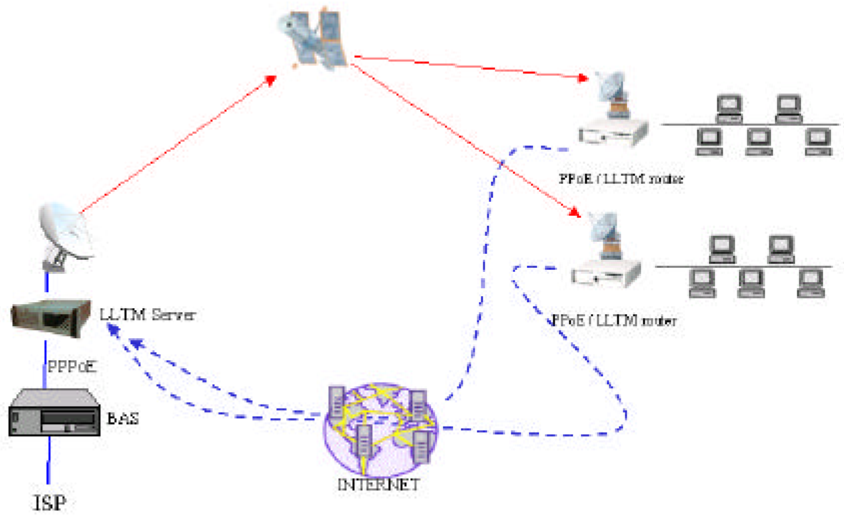

Figure 4 : Network architecture for broadband access

The Local Satellite Loop architecture offers the following advantages :

- Return channel flexibility : the use of UDLR allows the definition of an access network whether with a satellite return channel or with a terrestrial return channel. In addition a standby terrestrial link can be used automatically in case of failure of the satellite return channel.
- Multi-ISP configuration for the Internet access.
- Differentiation is made between the Access Service Provider and the Internet Service Provider;
- Complement with the ADSL network:
  - Performance: more than 128 kbps for the return channel and up to 40 Mbps for a gateway throughput.
  - Reduction of access costs: Re-use of the existing ADSL management system (accounting, billing, etc.)

4.1.2 Corporate intranet

Further to their suitability for broadband access services and content delivery services, satellites are a highly efficient in providing corporate intranet capacity to enterprises sites. In particular, many companies have highly distributed connectivity needs, in the case of retail outlets, or international agencies and partners. Services such as VPN connectivity, e-mail, content updating and streaming are increasingly in demand. With UDLR technology, providing such services via satellite becomes very simple. It also becomes very easy to deploy intelligent routing policies, optimising the use of the satellite. For example, multicast routing can be deployed over satellite links, keeping all unicast routing to the terrestrial links.

Barriers to deploying such solutions exist in the satellite access capacity. Satellite uplink gateways remain a significant cost. Specific emission rights are also required. Finally, the requirement to use the IP addressing of the up linker and the return link ISP may be seen as a major constraint. These barriers can be removed by using appropriate relaying technology above UDLR. It is possible to simply provide connectivity to the satellite and leave IP addressing in the hands of the end-user network administrator. In this case, the private network administrator can have full control over their network (e.g. IP addressing, routing policies, etc…), with the satellite capacity transparently integrated.

In this scenario it is therefore important to have robust connectivity between the company headquarters and the satellite uplink. This constraint will eventually be removed once satellite return link systems based on standards such as DVB-RCS will become more widely available on the market.

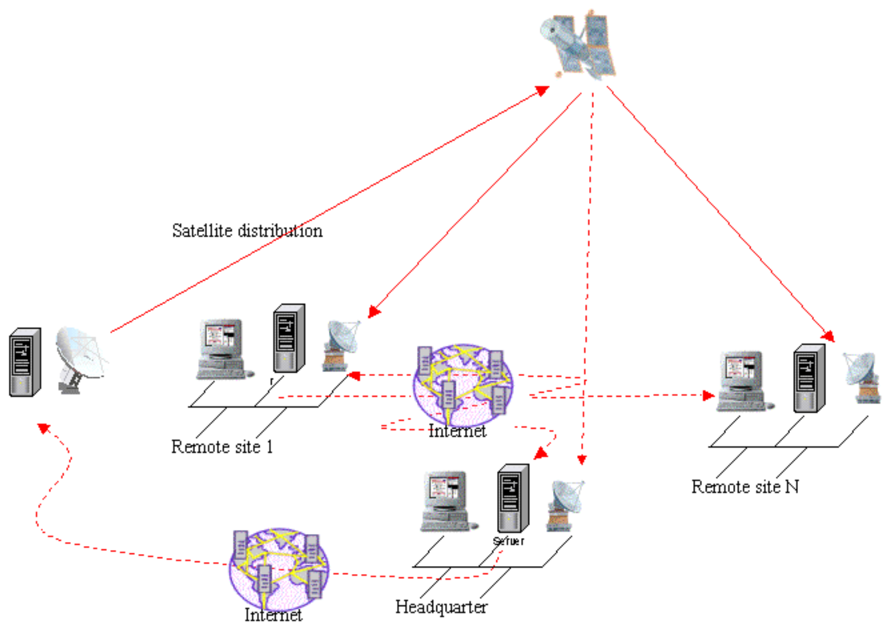

Figure 5 : network architecture for corporate intranet

In the future, such architecture shall be combined with content delivery solutions for the enterprise. According to a recent study perfomed by IDC [5] in November 2001, content network spending will grow by 50% during the next 5 years.

4.1.3 Mobile access

UDLR presents exciting possibilities for wireless connectivity to mobile or nomadic users, as illustrated in

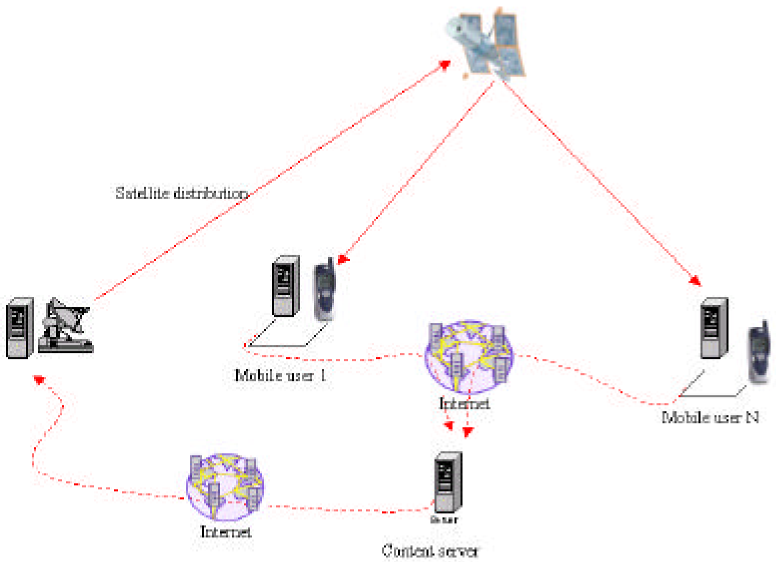

Figure 6. The downlink may either be via satellite, digital terrestrial (DVB-T (compatible for reception even when in motion)) or DAB . In each case, the mobile interactive uplink can pass via GPRS or UMTS.

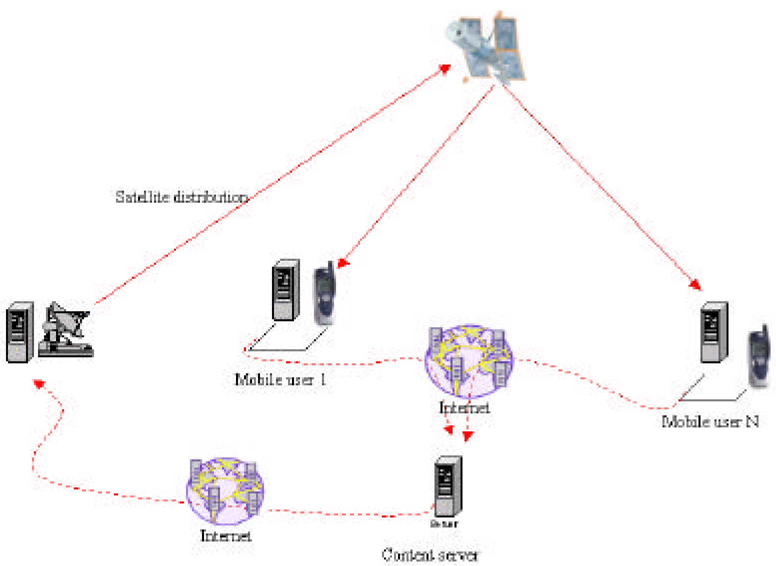

Figure 6 : network architecture for mobile access

UDLR is particularly suited as it is a link layer protocol able to support double addressing in IPv4 and IPv6. This architecture is hence particularly suited for UMTS networks which will be IPv6 native.

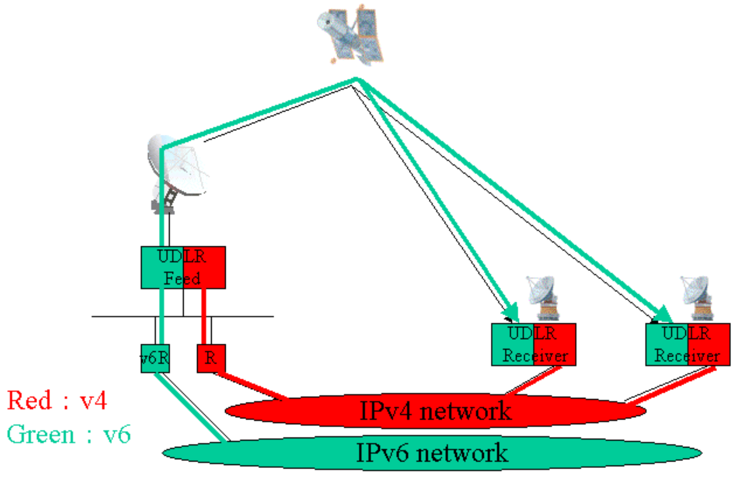

Figure 7 : support of IPv6 and IPv4 by UDLR

4.2 Content distribution

4.2.1 Content delivery

Satellite is a very efficient way to deliver rich content to potentially large sets of receivers at attractive costs. The applications are numerous such as video delivery to hotels and broadcast updating of caches and servers. The greater the number of receivers and the larger the size of the broadcasted files, the greater the interest in the satellite distribution option. The use of the return link depends on the user requirements, as detailed below:

- For video delivery to ADSL access points, the cost of the return link is negligible. The return link remains useful for the following functions:
    - to optimally control the adaptive FEC,
    - to acknowledge the received files,
    - to provide dynamic multicast routing to xDSL users.
- For audio and small sized message delivery, the use of the return link is not an absolute requirement, due the optimisation of downlink bandwidth being less critical for less intensive bandwidth content.
- For heavier applications such as rich multimedia delivery to kiosks or agencies, the use of the return link can be optimised, especially with those return links having a very low set up latency such as ISDN or GPRS.

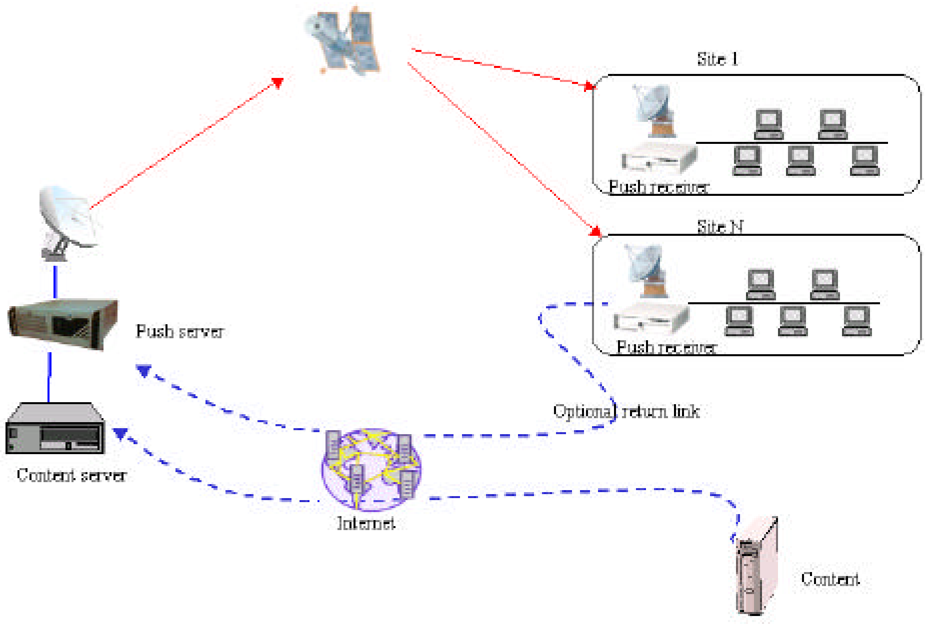

Figure 8 : Network architecture for content delivery

The interest of using satellite for content delivery is highlighted below in Figure 9 through a simple case study computation. In this example a full DVD movie of 4 Giga bytes needs to be delivered to a number of remote sites every day. Different transportation means are compared, such as surface mail, terrestrial communications, two-way satellite communications and finally satellite delivery with a terrestrial return link. The conclusions from the comparison shows that the UDLR solution becomes advantageous as soon as the number of sites rises above 40 sites (installation and hardware costs were included in the computation). Additionally, the following assumptions were made in the computation in favour of competing solutions (in particular terrestrial solutions):

- cheapest terrestrial access is considered available everywhere (although this is not true, with ADSL for example),
- when transmitting sensitive data, standard Internet access is used rather than having to build an Intranet (much more expensive),
- prices (e.g. for leased lines) have been taken from those countries where the telecoms infrastructure is the most developed and therefore the least expensive.
- PSTN is assumed to be already present at the end-site.
- No subscription fee is added.
- VSAT and DVB-RCS [4] granularity is assumed to be quite small, although in reality its availability is not complete.

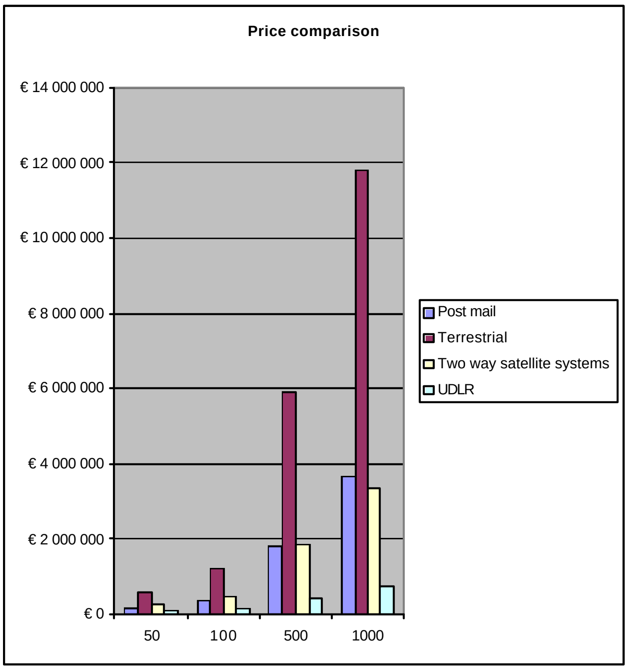

Figure 9 : price comparison for content delivery

4.2.2 Content networking

Content Delivery Network (CDN) technology and service providers have enjoyed significant growth[4] in the last few years. Due to the success of the Internet as a delivery platform, numerous bottlenecks have appeared between the content server and the end user. Beginning with the first mile bottleneck (origin server side), a multitude of web server acceleration products have emerged. In the 'middle mile' bottleneck, distributed caching networks avoid the high number of routers as well as alleviating the origin server, as proposed by the market leader Akamaï. Satellites, due to their capacity to broadcast/multicast content have taken an important role in the delivery chain, enabling content to be brought closer to the end user and especially to broadband points of presence. In such network configurations, connectivity is made between any broadband access point. The nature of this broadband access point can be xDSL, local radio loop, wireless Ethernet…

As a result, content can be located anywhere on the network or the Internet. The aim of the content delivery platform is to deliver it in the most efficient manner to all required sites. It is assumed that all the sites have the ability to receive the same content, either because the content is distributed by a common uplink, or because the satellite itself multiplexes this content on board. This is what we call any-to-any connectivity between the remote sites.

The return link itself may vary given the nature of the site and of the required connectivity:
- Direct terrestrial internet connection (Internet backbone for instance).
- Uplink to the satellite where the signal is multiplexed (Skyplex for instance).
- Satellite return link to a hub (DVB-RCS for instance).

The interest of the UDLR solution lies in:
- Its ability to manage heterogeneous configurations in a simple way such as multiple uplinks or various return links.
- Its ability to support IP multicast in a highly dynamic configuration both at routing and transport layers.
- The native support of many to many configurations.

When fitted with UDLR, content delivery networks have at their disposal a very efficient way to support their applications that optimises their bandwidth and hence their costs.

[4] Reaching Worldwide market size $1.63bn in 2000, and predicted to grow with a CAGR of over 30% over the next 4 years – Aberdeen Group

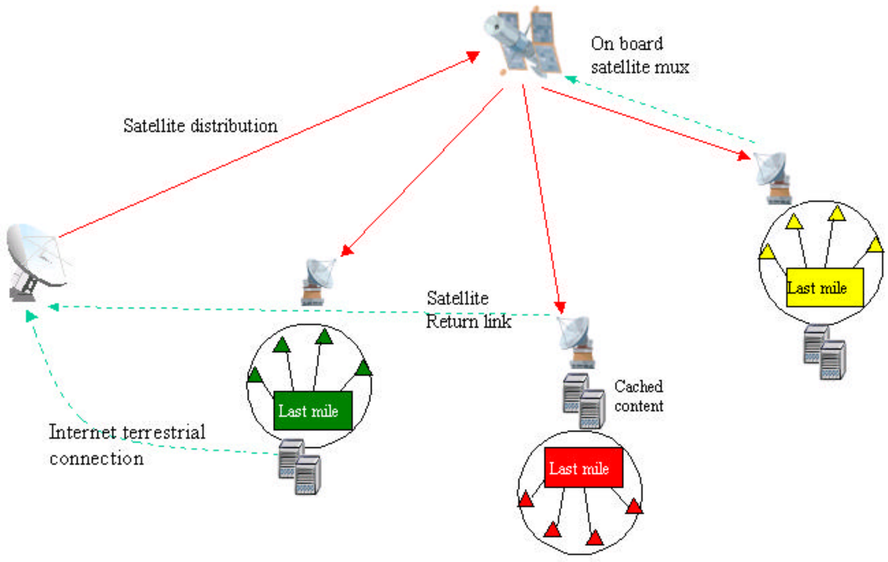

Figure 10 : network architecture for content networking

4.3 *Other applications*

Specific applications can be cited as being particularly suited for deployment over a UDLR mediation layer. These are mainly video-conferencing and distant learning. Several scenarios can be envisaged and are very easily deployed when using UDLR.

4.3.1 Video conferencing

Video conferencing by nature makes use of a back channel to provide interactivity between people taking part. Usually, participants use their terrestrial ISDN link to send images & sound to a bridge that performs the multiplexing between the different sources. As the number of participants is more important, it becomes harder to send that multiplex to all the others. The satellite brings a definitive plus for sending the multiplexed content to all the users.

4.3.2 E-learning

Using UDLR technology, it is possible to distribute multimedia content to a large number of students, including text, video, sound, executables… Moreover there is usually a return channel requirement to provide interactivity between the teacher and the students. This is also provided by the UDLR technology.

5 Conclusion

5.1 Summary

The convergence of voice, video and data across the Internet, and the ongoing unification of wide area and local area networks at home and in businesses for the seamless delivery of voice, video and data, requires new and cost effective ways of using the existing infrastructures and high capacity broadcast links such as satellites, digital TV and radio links. Broadcast links such as digital satellite links, digital terrestrial TV links and digital radio links are perfectly placed to address some of the key challenges of the Internet, such as rapid expansion, high speed access, delivery/access anywhere or anyplace. UDLR enables the use of the Internet in a full and transparent way across these highly efficient broadcast links.

5.2 UDcast vision

UDcast can help achieve this convergence in an extremely cost effective way. We provide the possibility to bring interactivity through different heterogeneous networks as illustrated in Figure 11. This vision is a reality today as one can see from the names of the validated products already tested in our laboratory. Broadcast flows are conveyed via satellite and interactivity is brought through a variety of access networks such as xDSL, PSTN/RNIS, GSM/GPRS and even INMARSAT satellites.

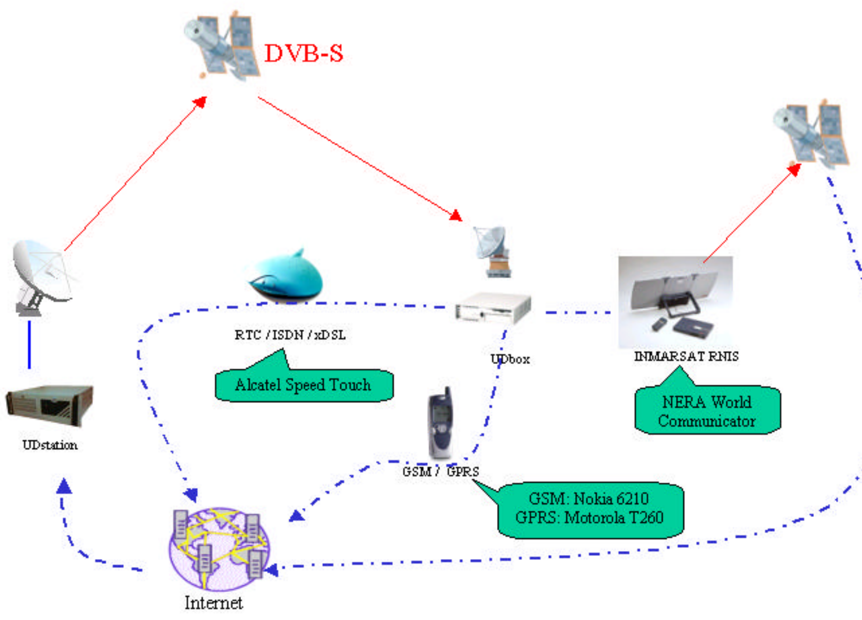

Figure 11 interactive broadcast networks today…

In the future, UDcast envisions extending the reach of its solutions to new terminals such as PDAs (Palm, Pocket PC, Simputer…) and new broadcast (from the DxB family like DAB and DVB-T) or interactive (like UMTS) links, as illustrated in Figure 12.

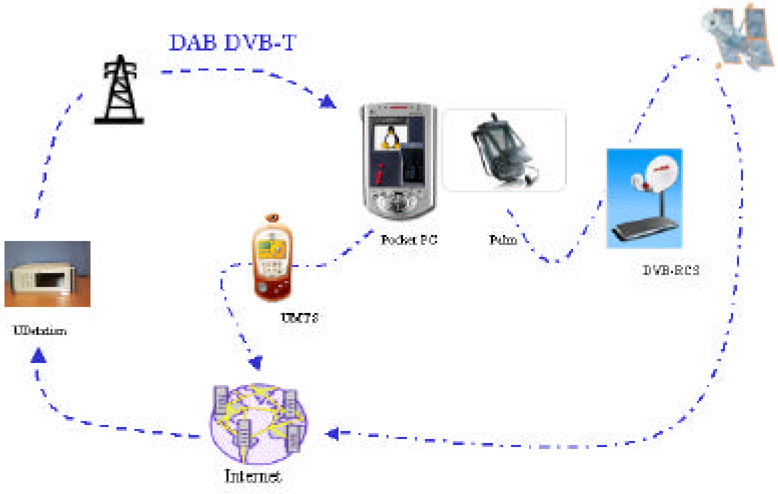

Figure 12: interactive broadcast network tomorrow

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[1] RFC 1701 Generic Routing Encapsulation (GRE) (S. Hanks - T. Li - D. Farinacci - P. Traina)

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[5] IDC (www.idc.com)

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