An Intelligent Integrated Approach to Multi-Service Residential Access Networks

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Abstract

TORRENT is an EU-Supported Framework V project, which is building a test-bed for multi-service residential access networks. With this system, home users will be able to choose, transparently, the most appropriate core transport network and physical access interfaces, in order to meet their QoS expectations for particular ranges and combinations of services.

1 Introduction

Connection-oriented networks have been favoured for services characterised by long holding times, few (e.g. two) parties in the call, low congestion tolerance, and often, high QoS needs and large data content. Connectionless networks have been favoured for services that are characterised by high tolerance to congestion, non-critical QoS needs or low data content, as well as for services of a multi-cast or broadcast nature. A single integrated broadband communications network is unlikely to be the ideal solution for all types of services.

However, a single physical access network that can cater for a range of different service and traffic types - whether they are more suitably supported by connection-less or connection-oriented transfer modes - is a way out of this dilemma. A single access network fosters simplicity for the customer. However, it should meet - in an optimal way - a user's service requirements including QoS parameters for cell loss and delay statistics, and also issues such as security, cost, and availability [12]. Bandwidth utilisation in access and core networks should also feature in these considerations [13].

Such requirements call for an intelligent system to be associated with the user's access network. This is an important feature of the system being developed by the TORRENT project [1].

2 TORRENT Architecture

2.1 Local Access Point

The heart of the TORRENT approach is an intelligent service-to-resource mapping (SRM) system. As figure 1 shows, the main functionality of this system is hosted in a local access point (LAP) to which the residential gateway (RG) of each of a number of residential users is connected. Each LAP will be made up from computer-controlled switching fabrics and will have interfaces for a number of local-loop technologies. On the core network side, the LAP will enable access to many service providers and core networks, be they based on IP, ATM, SDH, ISDN or even POTS. The RG of any user may be connected to more than one LAP, either directly or through another LAP.

The LAP will provide customer negotiation facilities including accounting. It will be able to handle authorisation of accesses to the customer for tasks such as metering, security monitoring and activation of residential equipment and devices. The LAP will also have facilities for Edge-of-Network-Processing (EoNP) to support consumer applications such as Video-on-Demand.

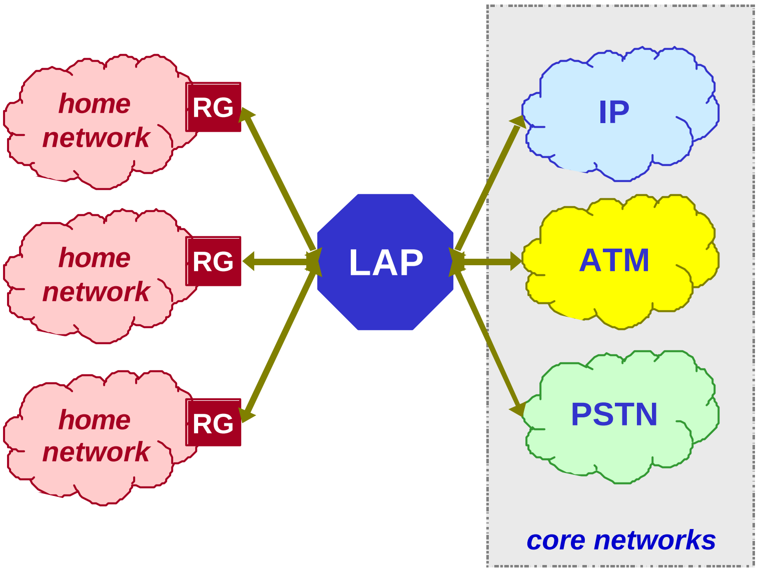

Figure 1: Architectural Approach

2.2 The Home Network

A major growth area will be the networking of, and inter-working between, residential equipment such as telephones, PCs, televisions, consumer equipment for heating, lighting and security as well as equipment associated with the supply of heat, light and power. Figure 2 shows how the home network fits into the TORRENT architecture.

TORRENT equipment is based on a standard and common protocol set being established for the open operating system Linux. This protocol set will cover the areas of the customer access point, the customer terminal (set-top-box) and the home distribution system itself. It will allow manufacturers of domestic equipment to install appropriate hardware and software interfaces to their products. Such interfaces will enable these products to be interconnected and controlled in a way that minimises the number of interfaces required. The home network itself may be built on technologies based on Ethernet, mains power lines or radio (e.g. HIPERLAN or Bluetooth).

2.3 The Local Loop

The local loop provides the interconnection between domestic users and the local access points. Although a wide variety of local-loop technologies, based on copper, coax, fibre and radio, are likely to coexist for some time, Copper-based ADSL is presently a strong contender for the support of multi-media services in the local loop. Whichever technology is used, provision must be made for a baseline telephone service for emergency situations, should a power failure occur.

2.4 Division of Functionality between the LAP and the RG

While there is some functionality that has to reside in the LAP and some that has to be hosted by the RG, there are other factors that will also influence how the functionality is to be distributed.

- **Bandwidth Bottlenecks.** It will be important to minimise bandwidth bottlenecks between the LAP and each RG. Potential mechanisms for this include traffic shaping and the use of priority queues.

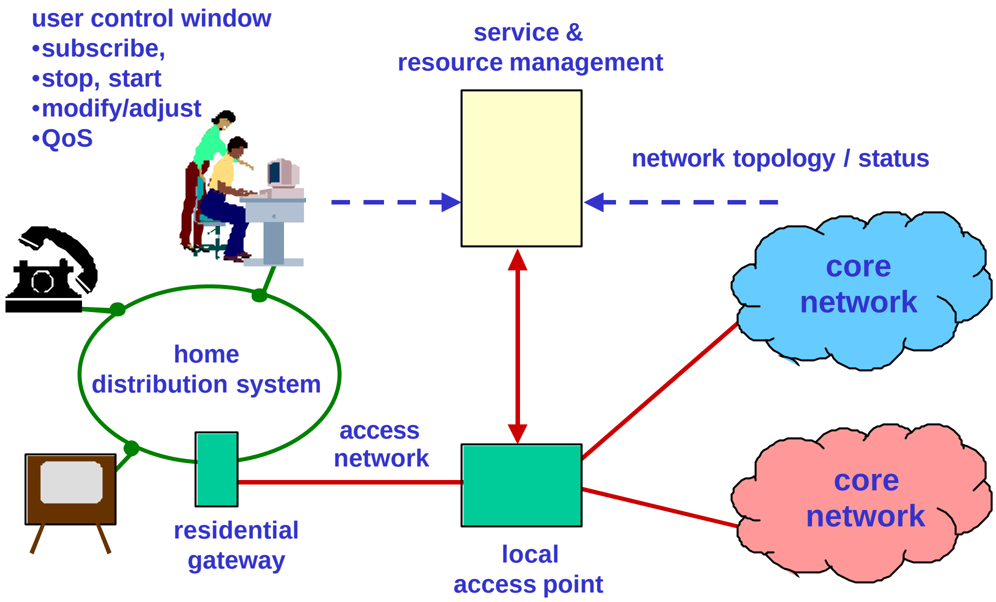

Figure 2: The Home Network

- **Processing Power.** The majority of the processing power required by each residential user should be provided on the LAP for the following reasons.
  - Technology and economies of scale suggest that it is cheaper to add processing power to the LAP rather than to the RG.
  - It is desirable to design the RG as a standard, low-cost, device to fit all residences including those having the most demanding requirements for processing power..
  - The RG should be made as simple as possible for the non-technical user.
  - The software in the LAP can be maintained and updated more easily by authorised outside parties than software in each of the RGs.

- **Scaling.** A challenge posed by shifting functionality from the RG to the LAP is the possibility of scaling problems on the LAP. The LAP may be associated with, say, 1,000 RGs, 1,000s of users, and 10,000s of information flows. In addition, performance drops sub-linearly with the scale of the task.

3 Service to Resource Management

The Service to Resource Management (SRM) Software is at the heart of the TORRENT project. It is novel in that it integrates the residential services including telephony, radio, television, Internet access and equipment monitoring. Innovation does not stop there, because the SRM software will be designed to achieve this by using novel agent technology to facilitate scalability, flexibility and a vast range of customer-provider negotiation scenarios.

User requirements such as availability, ease of use, flexible pricing structures, security, ease of installation and "painless" fault diagnosis and management are important driving factors for TORRENT's Service and Resource Management software system. The user expects the full range of telecommunications services, both traditional and yet to be conceived. In response to this, TORRENT intends to introduce file transfer, video on demand and voice over IP as part of its field trials. The bulk of the SRM system will be executed in the LAP that will therefore perform customer-provider negotiation, store customer preferences and provide the charging and billing capability. The structure of charging schemes will be derived from the work of EU projects such as CANCAN [2]. Importantly, the SRM system will also accommodate caching in order to support edge-of-network processing. Customers demand security, so the SRM has to cater for firewalls and be able to deal with rogue software.

The architecture of the SRM software is being developed to emphasise accounting in conjunction with session and call management. Its functionality, encompassing management, control and data planes, will cater not only for billing, session and call management. It will also provide for interaction with individual customers as well as with the multiplicity of network operators and service providers. Traffic monitoring involves interaction with low level packet handling facilities and is an important capability to support charging.

The functional blocks of the SRM software in the LAP can be formed into the following eight groups.

- Packet Handling
- Service Monitoring, Control and Management
- Choosing a Network Provider
- User Administration
- Technical Administration
- Accounting
- RG Manager
- Software Boot Manager

The agent platform, with which the SRM system will interact, provides an environment in which agents, representing customers, providers and network resources, can be created as required to support the user-provider interactions. Housekeeping tasks such as monitoring, charging and billing will be accommodated by the more traditional management approaches.

4 Session Granularity

Session granularity affects the implicit complexity of the TORRENT system. To look at this it may be noted that residential devices can be grouped as follows.

- media devices that do not support login
- media devices that do support a single login
- computer devices, which support only a single login (e.g. Windows boxes)
- computer devices, which support multiple logins (e.g. Linux boxes).

In this context, five candidate granularities have been identified.

- The RG (the coarsest possible granularity)
- An online residential device
- A user (i.e. a login-id)
- An application instance
- A user interface to an application (e.g. one of several Netscape windows)

Of these, the first (RG) granularity should be easy to implement but will be unacceptably coarse. The implementation of device granularity should be straightforward. The third (user) granularity is likely to be challenging in view of the need for user authentication and accounting. The implementation of User and Application Interface granularities is viewed as impractical at this stage.

5 Agent Technology

TORRENT will use agent technology for the SRM system. A software agent can be regarded as a software entity that can act in an autonomous manner, can learn (be reactive) and be proactive. A software agent can also interact with other agents, software systems and humans.

Agent technology reduces the need for centralised control and scales well with the size and capabilities of a communications network. This technology has been successfully applied in a number of communication projects dealing with the control of and service provision in, ATM and mobile networks (e.g. Bigham et al. [3]). Hence, there are several compelling reasons why parts of the TORRENT system should be agent-based.

- Agent technology provides a standardised mechanism for software components developed by different parties to interact. These components can potentially run on different locations, and/or migrate. Such mechanisms greatly simplify the TORRENT interface to components that may be supplied by network providers.
- Many agent platforms directly support high-level abstractions such as dialogues. This feature is needed by TORRENT because it enables component inter-working decisions to be documented and enforced at run-time.
- The agent model supports useful high-level abstractions - such as active-objects - not found in conventional paradigms.
- Agent-based systems have been used extensively in situations involving negotiation. Service negotiation is a key feature of TORRENT.

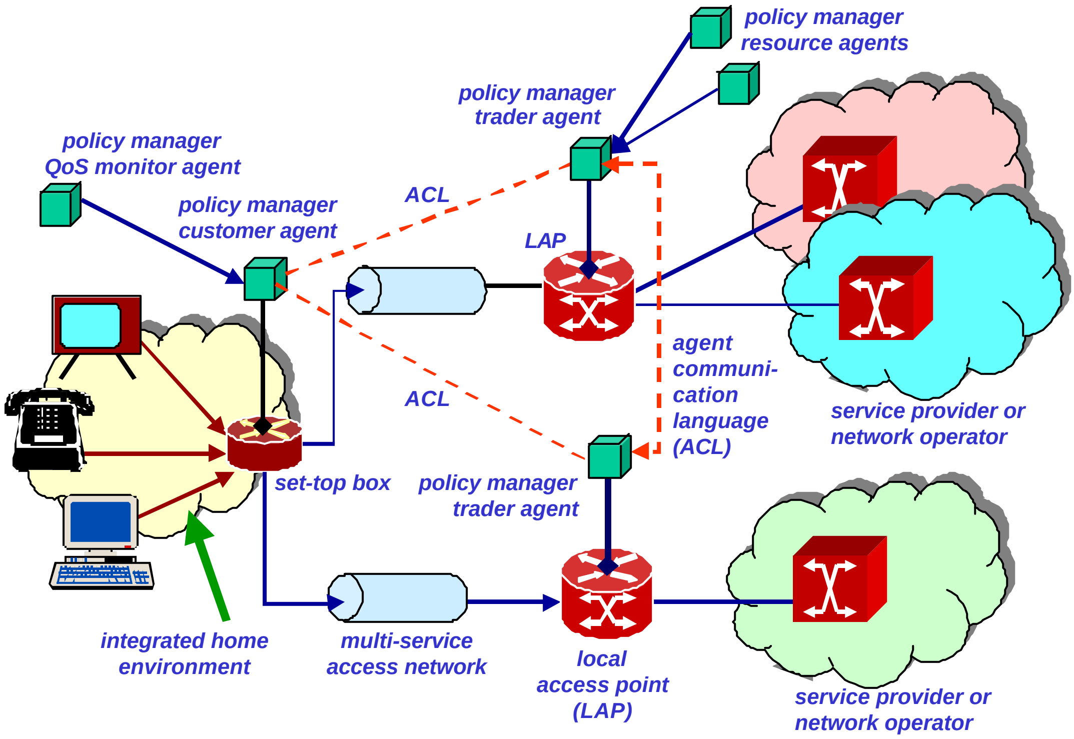

Figure 3: The Agent-Based System

However, the following aspects could present challenges.

- The latency caused by agent communication - and scheduling - may be excessive for some real-time activities.
- The performance of agent-based systems may not scale well. A TORRENT LAP may have 1000 or so RGs connected, so a LAP could potentially be running 1000s of agents. This could result in unacceptable performance.

6 TORRENT's Agent-Based System

TORRENT's envisaged agent-based system is outlined in figure 3. Customer agents will represent the interests of individual customers. Trader Agents will represent the service offerings of network operators and service providers. Agents will also represent accounting functionality as well as security and authentication processes. Importantly, agents will be able to negotiate on behalf of customers and service providers.

The design of the agent architecture will take cognisance of the IETF architecture [4]. This specifies three horizontal planes, namely the Policy Management, Control and User Planes. The Policy Management plane involves Service Level Agreements, Policy Data Repositories relating customers to their preferred service options, as well as Policy Repository Server Agents, Customer, Monitor, Trader and Policy Consumer Agents. These will rely on Control Plane protocols to access User Plane Resources.

The extended markup language (XML) [5] is a candidate for inter-agent communication. XML allows information to be stored in structured files and ported across different platforms. It covers both the vocabulary and the syntax of communicated messages.

A FIPA-compliant [6] agent platform will host the SRM software. Such a platform facilitates the creation and deletion of agents, provides agent communication channels and also makes available a directory facilitator system for finding agents.

7 Trials and Validation

To gain acceptance, software as complex as the SRM system must also be tested and validated. The candidate services for the TORRENT field trials are file transfer (FTP), internet access, video on demand and voice over IP. A number of features will be validated. These include the ability of the TORRENT system to provide services to customers quickly and easily and the ability to support the requirements of users, network operators and service providers. Metrics for the field trials include time-related entities, availability of resources and the accuracy and precision of data content and its representation. Security and cost aspects are also relevant.

8 Standards

To facilitate the acceptance of the TORRENT software by the commercial community, standards must be taken seriously. TORRENT will work with existing standards, and where necessary influence their creation and development. The activities of a number of well-known standards organisations (references [4], [6], [7], [8], [9], [10], and [11]) are relevant to TORRENT.

9 Conclusions

TORRENT will demonstrate the advantages for the customer of intelligent control over the choice of network operator and provider, and, parameters such as QoS, cost and security. The Service and Policy Management Framework (SRMF) is the core of the TORRENT access network test-bed. Agent technology, a management platform, packet handling, caching and support for accounting and security are all ingredients of this software. Standards issues and software validation are further important considerations associated with the realisation of the SRM.

Acknowledgements

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