CONVERGENCE

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Abstract

Convergence trends between the WAN Internet area, characterized by best effort service provision, and the real time LAN domain, with requirements for guaranteed services, are identified and discussed. A bilateral evolution is identified, where typical bulk service applications from WAN, such as multi media, migrate into the RT-LAN domain along with the need for extensible and easily maintainable technology, demanded by such applications, to coexist with QoS demanding applications on a common platform. Meanwhile QoS demanding dependable applications find their way out into WAN with the emergence of remote service provision, such as supervision and control of decentralized heating facilities and wind based electrical power production. The reliability issue is addressed from a structural viewpoint, where the concept of Structural QoS (SQoS) is defined to support reliability modelling in communication infrastructures. A graph theoretical approach is presented as an approach to reliability management in complex communication infrastructures. Real life examples are provided and specific problems are presented and discussed. Wireless technologies are discussed as a complement, providing not only mobility and installation ease but also a complementary failure profile.

1. Introduction

It is our claim that the ongoing convergence between WAN and RT-LAN is bilateral, since it holds both the migration of Internet traffic to the RT-LAN area, and the adaptation of the global information system to support dependable applications with high QoS demands. In addition, short-range wireless technologies approach a well-established position, supported by only a few unifying de-facto standards, such as IEEE 802.11b and Bluetooth. This last fact seems to impact the penetration of wireless technologies into dependable areas more than pure technical arguments.

QoS sensitive applications move onto WAN in two categories: non-dependable QoS sensitive applications like multi media and VoIP, and dependable applications like remote security services and remote control. Several studies of the former have been made, dealing with modelling traffic sources and network traffic modelling [1]. This research is mainly concerned with queuing and delay considerations under normal operation mode.

For dependable applications, additional issues regarding system failure remain to be considered. Long term reliability and availability requirements need to be specified. From a provisioning viewpoint, policies for operation under failure, supporting graceful degradation, are to be specified. Provisioning service to dependable applications should be based on pre-negotiated QoS contracts, including guaranteed reliability levels based on thorough reliability modelling, involving the current customer portfolio, failure policies, as well as the underlying network infrastructure. The liberalization of telecom service provision is complicating the process by keeping relevant infrastructure information hidden from the end-to-end service provider. Conversely, multi media services for e.g. surveillance and supervision purposes migrate into traditional control system areas.

Wireless technologies complement their wired counterparts both in the broadband and in the real time LAN domains, i.e. tedious cabling may be avoided and wireless communication obviously facilitates mobility.

Wireless technologies exist in the global infrastructure, ranging from satellite and radio link communication over Fixed Wireless Access (FWA, IEEE 802.16) to a LAN and PAN level with existing short-range technologies like DPRS (EN 301 469-1), WLAN (IEEE 802.11b) or Bluetooth (IEEE 802.15)/[2] and home-RF [3] along with experimental technologies like HIPERLAN (EN 300 652) and Ultra Wide Band (UWB) [4].

Generally, wireless communication technologies suffer from limited bandwidth and less reliable link services. We suggest wireless technologies for improving the overall reliability of an entire communication facility, since failures in wireless links are basically of a different nature than for wired links.

The paper is organized as an introduction to the concept of SQoS along with an overview of the global information infrastructure. This is followed by an example of real time applications migrating to WAN environments, describing a technical network under implementation inside a local Danish municipality. The ATOMOS standard is presented along with the reliability issues behind the standard. Wireless communication protocols are presented and discussed w.r.t. QoS and suggestions for their roles in improving SQoS are put forth. Finally, concluding remarks are given summarising the standpoints presented in the present work.

2. SQoS and Topology

Structural QoS (SQoS) is a novel concept introduced in [5], dealing with QoS parameters primarily related to architecture and structural properties in the infrastructure. SQoS forms the base for support of a variety of services established across the infrastructure, demanded by the communication services. Requirements relate primarily to delay, reliability and capacity issues, and are specific for the individual types of applications using the communication service in question. Explicit knowledge of the inherent topological properties is important in order to provide a viable platform for providing differentiated SQoS.

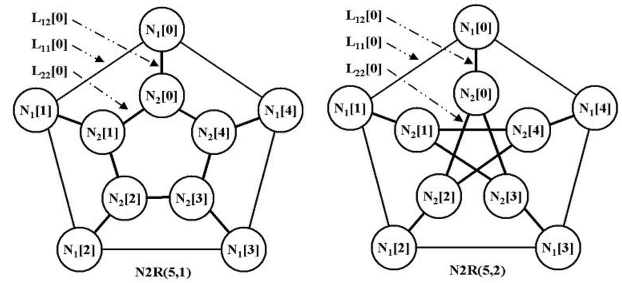
The backbone infrastructure in a WAN network is today typically built as a meshed network interconnecting a number of local fibre optical ring structures, extending into part of the MAN area. The nodal redundancy is obtained either by duplication of equipment or by geographical diversity. Although the backbone structure allows for at least triple connectivity globally, most operators have chosen a service provisioning strategy based on ring structures at this level as well. One reason being, that this choice is supported by automatic restoration algorithms on the optical fibre level, and the fact that the meshed structures in general are build in an ad-hoc manner. The latter is causing a complex time-consuming restoration algorithm, generally unsupported. This is preventing the full utilisation of the inherent potential for higher SQoS. For the support of mass driven demands with low reliability, the ring structure based automatic restoration in the WAN/MAN area is sufficient, given that the last mile access in general only allows for single line connectivity. For higher SQoS demands, automatic restoration cannot compensate for the permanent availability of more physically independent lines.

A straight forward possibility is to combine the wired and the wireless based network in a joint service-provisioning platform in the MAN area, offering at least the potential for dual independent access for the end-user, and to a large extend even more. This is opposed to the actual situation where the radio based access network is seen as a competing technology to the wired networks. The prerequisite is a careful planning of the placement and linking of the base stations in the radio-based networks to avoid dependencies with allocated channels to the end-user in the wired networks.

Applying structuring principles beyond the level of ring network topologies is a promising complementary approach. To avoid the complexity in the meshed networks in general, an approach based on regular graph structures is investigated. By applying methods from graph theory, rather large structures can be handled with a realistic computational effort. For illustration, consider a family N2Rpq of regular degree-3 graphs. N2R(p;q) can be described as two interconnected rings:

Nodes: $\{N_1[i] \text{ U } N_2[i]\}$;
Lines: $\{L_{11}[i] \text{ U } L_{22}[i] \text{ U } L_{12}[i]\}$
$L_{11}[i]$: Line $(N_1[i], N_1[i+1 \bmod p])$
$L_{22}[i]$: Line $(N_2[i], N_2[i+q \bmod p])$
$L_{12}[i]$: Line $(N_1[i], N_2[i])$

$0 < i \leq p$; p and q are integers without common prime factors, $p>2$; $1 < q < p/2$.



N2R(5,1) N2R(5,2)

N2R(p;1) correspond to the double ring architecture. N2R(5;2) correspond to the Petersen graph. The N2R(p;q) family allows for the provisioning of a static routing scheme, with global knowledge of distances and paths across the network and therefore also a predictable and specified base for delay and reliability calculations. The highest SQoS demand that can be provided on a global scale in N2R(p;q) is a triple set of dedicated independent connections between any two points with a predictable upper limit for the delay variations between the 3 connections. For any specific value of p an optimal value of q can be calculated with respect to minimizing the resource consumption for the service provisioning.

In [5] and [6] a detailed analysis of networks with a SQoS potential is provided, in order to investigate the viability of a systematic approach for a specific representative area. As a special case, a Swedish model [7] is analysed. This model is based on a logical square structure with local recursive refinements.

3. Global Infrastructure

The global infrastructure can be described as a huge population of Personal Area Networks (PAN's) or field level busses, a variety of customer premises networks (LAN's), a set of copper or radio based access networks (Man's) interlinked by a set of fibre optical based backbone networks (WAN's).

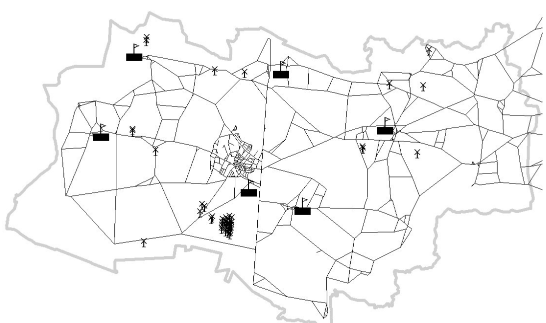
The IT infrastructure has evolved from a set of more or less vertically integrated networks dedicated to specific application service types, moving towards an interworking set of horizontally integrated and converging infrastructure platforms common for literally all services. The complete digitalisation of voice and video services making this evolution possible forms the base for convergence. It also opens for the potential of bringing data and telemetric services with strong QoS requests into the MAN and WAN area, previously limited to the LAN area due to the relatively high costs in dedicated leased line based MAN and WAN sub-infrastructures.

WAN. The backbone networks (WAN's) are typically built as interconnected sets of optical rings with SDH and ATM equipment. The structure originally followed the structure in the telephony networks, but is evolving more and more in direction of ad hoc networks, not following an overall commonly agreed upon architecture. This makes the possibility of establishing well-specified global infrastructure services increasingly difficult.

Under existing policies of a liberalised telecommunication marked this could lead to a replication of the existing architectures as well as an infrastructure only covering the most profitable areas in the densest populated areas. That would prevent the possibility of extending services with stronger SQoS demands to the wide area on a global scale and thereby missing a large-scale new market potential. This situation has now finally been recognized by both industry and the public authorities. EU initiatives are in progress for the coming period to find solutions to this problem.

As part of a Danish national program [6] for promoting a modern IT based society, an investigation has been made in the analysis and design of a new access network architecture in the local municipalities in the Northern Jutland region (6000 km^2 and 600.000 inh) taking advantage of the opportunities in the situation. The outcome is a strategic long-term development plan for the area. An important element in the plan is a new fibre optical MAN with FTTH and carrying an identified set of virtual networks reflecting the variety of SQoS demands implemented in a common infrastructure.

The most ambitious part of the plan is a virtual technical support network that allows for distributed real time control application throughout the region with committed global delay and reliability parameters.



One of the participating municipalities (300 km^2 and 25.000 inh) has been actively contributing to investigate and implement elements of a new MAN infrastructure along these lines. The first advanced application target is a shared surveillance centre for seven smaller heating and electrical power plants distributed over the municipality.

The long-term goal for this application is a shared control and operational centre for real time coordinated production regulation amongst the plants, including a relatively large amount of electricity producing windmills with a reliability corresponding to the present on-site quality.

MAN. The most widespread types of copper based access networks (MAN area) are based on the existing telephony access networks or cable TV distribution networks, with no possibility for redundancy in general. The wireless networks complete the picture with mobile as well as fixed access. The explosive evolution in access capacity calls for an implementation of an entirely new access infrastructure based on optical fibres to the home and complemented with next generation wireless technology.

LAN & PAN. For production plants of significant size, a number of available communication technologies exists. Commercially a limited set like devicenet [8] , profibus (DIN 19245) and EcheLON (ANSI/EIA 709.1) seem to dominate. In [9] it is argued that an automation LAN should cover 3 separate areas; a top administrative level, a mid real time level and a hard real time field level, and should be technologically separated accordingly in order to support specific QoS levels characteristic to each level. Other arguments, such as flexibility, ease of maintenance and SQoS issues, point away from such a separation. In the EU funded ATOMOS I project [11] a communication standard for marine automation was based on a single technology, ARCnet (ATA/ANSI 878.1), covering all three levels. Reliability was at that point accounted for in the shape of replication at a segment level, i.e. double NICS and cables comparable to class 1-2 configuration in TTP [9] . From an SQoS viewpoint two critical points associated with such an approach may be identified; requirements for physical cabling remains unspecified leading to possible dependent cable damage, and structural reliability issues are unspecified outside a segment level. Overall SQoS considerations would lead to architectures where segments act as vertices in topologies with well specified SQoS properties.

In unified network architectures, all three of the above traffic categories should coexist on a single media. Trends towards integrated "intelligent" components, e.g. pumps with http interface, facilitating "thin clients" or AC motors with integrated velocity controls naturally pulls the traffic profile away from the hard real time field level towards a mid real time level with modest RT requirements. Deterministic network calculus [1] from real time analysis in ATM networks is applied in [10] to bursty real time traffic in the ATOMOS architecture.

Evolution in standards and technology has brought wireless communication to a significantly larger application area lately. Standards and technological implementations exist for a variety of applications ranging from global satellite communication to local communications in the centimetre range with Bluetooth power level 1. In between, we find radio link, wireless access, mobile telephony, wireless LAN, and wireless PAN technologies. Most of the mentioned technologies are primarily intended to support merely bandwidth demanding applications like voice and multi media. It remains an open question, which role such technologies are to play w.r.t. dependable and delay sensitive applications like distributed feedback control. Wireless transmission suffers from notoriously high bit error rates, i.e. 1E-5 to 1E-3 compared to 1E-9 in wired links. However, with redundancy coding like the 1/3 FEC, Bluetooth supports a rate of 800 16-bytes frames pr. Second at an error rate (FER) within 4E-8 to 4E-4, when used as a point-to-point wireless connection. Thus at a field level Bluetooth may act as a sensor/actuator bus at ranges up to 10 metres. However, Bluetooth power consumption may be far too large when battery life times above 2 years are required. Superior bandwidths at all ranges are reported from UWB experiments at power levels 13 dB below Bluetooth. Commercially available solutions are still far above tolerable power levels for battery-powered applications.

At an increased range level, consider remote and distributed control of decentralised heating facilities and windmill parks. Wind mills are typically located in rural areas so wired communication lines are bound to pass fields used for agricultural purposes, increasing the risk of line break. For such a situation FWA technologies at nominal bandwidths up to 2 Mbps and ranges from 1-10 km seem appropriate as backup lines or hot stand by. At shorter range, and considering the ATOMOS network, the intended increase in reliability may be significantly reduced in fire situations where replicated cables are likely to be damaged simultaneously. Wireless backup communications should be considered at an early stage in an integrated SQoS design process to secure communications vital to dependability in e.g. fire situations. The IEEE 802.11b standard seems appropriate for such a task considering both range and bandwidth.

4. Concluding remarks

In the picture of a converging global infrastructure, some of the problem areas have been highlighted. The introduction of an SQoS concept points to new systematic approaches in order to create support for dependent applications with high reliability service demands.

In the LAN and PAN environment, the technologies are ready, and the challenge lies in improved architectures encompassing the system integration process. Opposed to the actual WAN situation, the fast increasing density of interworking wired and wireless components leaves plenty of room for establishing sub-network topologies with high SQoS potential. This, on the other hand, gives problems in maintaining SQoS based substructures within mobile components, as the high potential for sub-structuring at the same time calls for improved strategies for the selection and maintenance algorithms in the wireless line and nodal space.

A key focus point in the next period should be the MAN environment, as the component in the global infrastructure with lowest SQoS potential. Based on the explosive capacity-driven demand, we are confronted with the need for a complete re-implementation with fibre optical technology, complemented with new wireless technology. This situation gives a historical chance to create an improved global infrastructure with an overall high SQoS potential extended not only to the MAN level, but also all the way to the WAN level. The density of branching points in the new fibre optical structures will increase from an average of app. 0,04 to 1 per sq km. By careful planning of the MAN it will leave room for an extremely low cost complementary set of lines in the WAN back-bones.

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