Managing information systems infrastructure: lessons from a VOIP-system implementation

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***Abstract*—**Information systems infrastructure is increasingly being used also as a backbone of telephone systems. This is result of VOIP-based telephone systems which replace analogue PBX centres in organizations. IT departments are in pressure - not only do they need to verify the existing infrastructure, make development plans, investments and implement more advanced devices but also they will be acting as phone support personnel.

***Keywords*—**Information systems, telephone, development, VOIP

I. Introduction

INFORMATION systems and business applications depend on the smooth operation of the information technology infrastructure (IT infrastructure). It consists of different technologies, hardware devices and software that enable communications. Planning, developing and implementing complex, constantly changing, expensive technologies and turn them to working solutions that serve users on a daily basis puts great demands on those who are involved in the development process.

IT infrastructure management is a combination of three main elements [1], [2], [3]: the first includes management of technical components, like computers, network devices and software that are required in data transmission. The second element consists of services which are shared across the organization. For example, the maintenance of databases and data processing hardware are often shared in many functions and units in the organization. The third main element is the human component: management of knowledge, IT skills and experience are vital in successful IT infrastructure management.

The role of IT department is critical in management of information systems infrastructure. Here the interplay between organizations business management and IT-department has a key role. However, there are also external factors that are important here. Different service providers and vendors together with customers and business partners influence infrastructure management [4]. Information systems development is influenced also by innovations in information technology and other fields. As a result, new devices and software components need to be integrated with existing infrastructure. Interruptions in operations and other weird problems indicate that installing new technology may not always have desired results.

This paper deals with management of IT infrastructure: with actions that are related to the maintenance and development of an organization's basic technological platform. Here we will look especially at the challenges that are related to integration of IT infrastructure and telephone systems. We approach these challenges by looking at an organization which installed a VOIP-based telephone system.

II. IT Infrastructure and traffic management

In most organizations are information systems in a critical role. Therefore it is essential that these systems function reliably and correctly. This is also referred to as trustworthiness of the technology [5].

In general, the operation of conventional business applications and computing are usually not sensitive for delays in data transfer infrastructure. However, this is not the case with audio where even short delays can easily be noticed by human ear. As a result, the performance of IT infrastructure is an important issue.

A. Bandwidth and high traffic

Bandwidth is the concept which is here used to describe the performance of the infrastructure. It is a combination of factors such as data transfer speed, number of transactions, average file size, network topology and traffic patterns [6]. Bandwidth is somewhat complicated issue because it is result of constantly changing traffic factors (mainly files being sent over the media and number of transactions at a given time). Therefore, the available bandwidth changes based on network utilization and it is possible that high network usage causes problems. The situation is known as congestion, and it can impact the performance of the network seriously [7]. As a result, bandwidth or traffic management is an important task for IT infrastructure management.

Both the network utilization and throughput increase as the load increases. Should the load continue a saturation point will be reached (point A) where throughput continues to increase but not as rapidly as with smaller network load. After this saturation point network is moderately congested, the network components use their buffer memories in routing and forwarding data transmissions. The network is still operational, but response times are increasing and the system feels "slower". However, if the network load continues to increase the total throughput starts to drop fast (after point B). This is because network buffers overflow, packets get timed out and duplicates will be sent. The result is that total amount of traffic increases rapidly making the situation worse. At very high traffic, performance collapses altogether and no packets can be delivered. [8], [9], [10]

B. *Traffic management*

Network traffic management deals with the efficient use of the network infrastructure, and it is highly needed when load is high. The challenge is to manage congestion; keep traffic below the level at which performance starts to fall so that the quality of services (QoS) remains high [10], [11], [7].

The IT department can approach traffic management with two main methods [6], [10]. First, performance can be managed by splitting the network infrastructure with switches, routers and bridges into smaller parts. In this way heavy traffic in one part of the network remains in that part and does not affect other parts of the infrastructure. The second way to increase bandwidth is connected to mapping the network infrastructure; the goal is to find the slow connections and bottlenecks. These should then be upgraded with faster connections and technologies. Both approaches - splitting the network and upgrading slow links - can be used simultaneously, ant they may significantly increase the available bandwidth. However, it is still possible that not all congestion related problems can be avoided, especially in places where the performance is relatively limited. For example, in distant satellite offices the connections to headquarters may have “slow links” due to high costs of bandwidth. It is also typical that mobile users have limited bandwidth in use.

What happens in a high load situation? When a network node becomes severely congested network nodes start discarding packets and re-transmitting it later. This means that congestion at one single node in a network can quickly affect the throughput of a larger part of the network: under high traffic load re-transmissions make the situation even worse because more and more packets are being transmitted. In order to avoid the situation traffic may be controlled before sending it. This is referred to as shaping, which smooths traffic by storing it to buffers already at the sender. Also buffer memories are typically used throughout the networking devices so that network devices store peaks and bursts from transmissions to buffers. Congestion management includes also traffic policing, i.e. decreasing the priority of the bursty traffic and even discarding it. [9], [10], [11]

There are different techniques that can be used in peak traffic situations in order to manage congestion [10], [7]:

- Implicit congestion signalling: if the source node can detect increased delays and packet discards based on end-to-end behaviour is this implicit evidence of network congestion.
- Explicit congestion signalling: network alerts source node of increasing congestion so that it can reduce transmissions and thus decrease the congestion.
- Backpressure: a node that becomes congested is able to slow down or halt the data stream from the sending node.
- Choke packet: a congested node generates a choke packet and sends it to the source node, informing it to reduce the rate at which data is being sent.

The problem with traffic management is that it may not treat all network users and nodes fairly [7]. If the network node is able to maintain queues for each connection or source-destination, the queues with the highest traffic load discard packets more often than links with lower traffic. In addition, congestion management has to deal with the problem of prioritizing - it is not enough that all users get same priority. For example, servers should have more bandwidth than clients.

Traffic management may not help in all situations: it is likely that the overall throughput of the network will drop if all users or nodes try sending as much as possible all the time. For example, P2P-applications can consume all possible bandwidth. Traffic management cannot solve this alone, also cooperation, regulation and policing is needed. Otherwise selfish use of congestion controlled network capacity may have disastrous effects [12], [13].

It is also important to look at the type of data that is being transmitted [11], [7]. Interactive applications, especially transmission of video and voice require a steady data stream, whereas others, like e-mail, are rather insensitive to delays. Here it is important to allocate bandwidth and prioritize so that these packets can be delivered smoothly in time [11]. QoS calls for prioritizing of different data types, and it may involve hardware upgrades if existing network devices do not allow it.

To summarize, traffic management deals with congestion control. Firstly, increasing traffic load needs to be detected so that correcting actions can be made. Secondly, congestion control should treat different users and data types wisely in order to maintain the quality of services.

C. *Implications for audio data*

Data types that are sensitive to delays in the network require traffic management. Situation where there is too much traffic or the traffic is poorly distributed are critical for audio requiring steady transfer rates travelling over the network. Increasing bandwidth does not necessarily help; even short bursts can cause packet dropouts.

Prioritizing based on data type and application is often the answer, it can provide the required quality of service also during heavy network load [11]. Quality of service is guaranteed by reserving a certain, predefined minimum bandwidth for these types of applications or data transmissions [10].

Traffic management is very important with audio data. When audio is being sent as IP-packets over computer networks the quality of the audio data must be guaranteed (VOIP). In heavy traffic situations overload leads to audible interference. As a result, congestion control techniques such as dedicated bandwidth for audio and fair queuing algorithms are needed.

III. CASE EXPERIENCES

In this chapter we look at challenges that were met in integration of information systems infrastructure and telephone system in a municipal organization. This organization had been using an analogue PBX-system for years, and now something should be done to the legacy system. The systems provider (local telephone operator) had in several occasions mentioned that the old PBX-system should be upgraded as there were no longer updates or support available for this model from the manufacturer. It was clear that if the system would not be replaced it would fail – sooner or later. Should any larger failure occur the results would be dramatic.

Once the situation had been understood in the top management group of the organization the next step was to map different alternatives, costs and make a preliminary implementation plan. Here one issue was who should be responsible for this: earlier the administrative department had been the contact to telephone operator in telephone system related matter. Now it was found that the telephone systems are more or less computer-based and sending calls over the computer network is one feasible alternative, even though continuing with analogue systems was also possible. This is why organizations IT department was involved in the project from the beginning.

A. Towards VOIP-technology

Discussions with the current systems provider indicated that upgrading the analogue PBX-system would be very expensive. It would require changing the software and making large investments in PBX-hardware. The price tag would be so high that switching to a totally different system – computer-based VOIP-telephone central – might offer better price and functionality. In this case open bidding would be used in order to map the best possible alternative and systems provider. If the system would be upgraded no open bidding would be required, and also changes to existing practices would remain minimal. This is not the case with a computer-based telephone-system – it is expected that it would call for lot of work, both in the planning phase and in the implementation.

The organization decided to use an outside consultant to map the alternatives and make the feasibility study. Using an independent expert was seen necessary; it freed resources from a time-consuming study phase. Another important issue was that the telephone systems were large and complex, especially if telephone system is going to use the same IT infrastructure as is the computer-to-computer systems. Moving to computer-based telephone systems would require changing the analogue telephone signal to digital, but this would not be all. Changes are probably required also in the underlying IT infrastructure so that data from computers and audio from telephones could smoothly move throughout the network.

Mapping the alternatives took a rather long time, almost half a year. The consultant worked together with the administrative department and IT department. Here issues like number of telephone in different departments and units, types of connections between departments and quality of the existing IT infrastructure were studied. Also current operating costs would be needed so that alternatives could be compared against current costs.

What was needed was comparison of investment and operating costs in different alternatives that potential system providers were offering. The goal was to be able to with confidence make the right choice from known alternatives. Technical details would be studied once the main technological solutions and systems providers were selected based on consultants work. Possible system providers were mapped, and they were asked to offer solution that is based on analogue technology and VOIP-technology.

Ultimately, the selected solution was based on VOIP-technology. Based on consultants work this alternative would be the most inexpensive and offer most features given the money spent. However, as a result of the competitive bidding this means that there will be a new system provider.

The decision had been made, and was time to go forward with the project. It was soon found that the new partner had practically no project management skills. A considerable part of the project work was to be done by organizations own IT department. In fact, practically all advancements in the VOIP-implementation project were result of the IT department efforts in making things happen.

Cooperation with existing PBX-system provider and partners in local area network management is important in the case organization. The first partner is a regional telephone company which was responsible for all telephone calls made through leased lines. Likewise, this partner took also care of computer networking between organization's headquarters and satellite offices (there are almost 15 offices with variable number of users and computing devices). The second partner has an important role in management of the networking infrastructure in the headquarters; especially the firewall management is a critical task.

B. Infrastructure analysis

The VOIP-project was based on the preliminary study done by an outside consultant. However, this study concentrated more on the costs on and did not look at technical details. The IT department was merely asked “whether the IT infrastructure is capable of handling VOIP”. As the project moved to implementation phase it was found that this is approach was all too general as each office and link has to be studied individually: networking technologies, capacities and devices must be mapped one by one. Consequently, the decision makers were focusing on investment costs (PBX-hardware and software) and operating costs. The infrastructure-related costs and development needs remained rather uncharted.

The detailed analysis of IT infrastructure took a long time, required plenty of extra work and revealed that a considerable part of components and devices in the infrastructure need to be replaced by more advanced devices which allow bandwidth management between voice and data transfers. In the headquarters the infrastructure was good enough, but in practically all satellite offices devices had to be replaced. The result was that hardware related investments were considerable. In fact, as the IT manager told "had they [investments] been known in the beginning another kind of solution might have been chosen".

Replacing old devices in the infrastructure to more advanced ones which allow designating bandwidth for calling purposes was a crucial step for the VOIP implementation. Otherwise heavy traffic would be likely to cause problems in telephone calling – a situation to be avoided. This was an important investment for the infrastructure, VOIP-project made it possible to change old technology into new, legacy switches were replaced with new and advanced switching technology. If there had not been this project it would not have been possible to invest this much in network infrastructure, told the IT manager.

Another action that was taken at this point was increasing connection speeds between satellite offices and headquarters. The results from IT infrastructure analysis indicated which links were possible bottlenecks, and thus were upgraded so that more bandwidth would be available for both calling and other computer data transfers.

IV. Conclusion and Discussion

Information technology infrastructure plays a critical role in organizations because all other systems depend on it. Today telephone systems are being integrated into IT infrastructure which was originally developed for computer-to-computer connectivity. One of the key features of VOIP technology is the bandwidth requirement for audio. As the data stream in telephone calls is continuous by nature there is no room for delays of any kind – interruptions and poor quality will immediately be noticed by users as. This puts great demands on networks, and requires analysis of existing infrastructure [10].

Firstly, it is important to guarantee enough capacity for calling purposes so that heavy computer use would not affect telephone calls running through the same connections. This can be done by designating capacity for telephone data; configuring switches and other active devices in the IT infrastructure is needed.

Secondly, robustness is a key issue in telephone systems. IT infrastructure is highly dependent on electricity, and so are VOIP-telephony systems. If there is power interruption also telephones are not operating. In a crisis situation this would be a disaster. Mapping the consequences of malfunctions in IT-infrastructure is needed.

The quality of telephone calls over computer networks is important. In the case environment this was approached by separating telephone traffic from other traffic, capacity was prioritized for calling purposes on network hardware level. It was learned that traffic management needs to be a part of the infrastructure planning. Another important notion is that integration of telephone systems into IT infrastructure calls for reliability and robustness in the whole infrastructure.

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