THE COSMOS INTEGRATED IT SOLUTION AT RAILWAY AND MOTORWAY CONSTRUCTION SITES - TWO CASE STUDIES

RECEIVED: April 2003
REVISED: July 2003
PUBLISHED: October 2003 at http://www.itcon.org/2003/21/
EDITORS: Robert Amor and Ricardo Jardim-Gonçalves

Andreas Meissner
Fraunhofer IPSI - Integrated Publication and Information Systems Institute, Darmstadt, Germany
email: meissner@ipsi.fraunhofer.de

Ioannis Mathes
INTRACOM S.A., Peania, Greece
email: imath@intranet.gr

Lito Baxevanaki
INTRACOM S.A., Peania, Greece
email: lbax@intranet.gr

Giovanna Dore
Omega Generation srl, Bologna, Italy
email: dore@omega.it

Cherif Branki
University of Paisley, Paisley, Scotland
email: bran-ci0@wpmail.paisley.ac.uk

SUMMARY: *This paper presents two case studies on installations of the COSMOS Integrated IT Solution, which we developed to provide "COnstruction Site Mobile Operations Support". We first give an overview of the entire system, discussing our network architecture, applications, workflow solution, and middleware, and then describe how COSMOS was deployed and used at a motorway and a railway construction site. Key effects on the construction companies' business operations are reported.*

KEYWORDS: *Construction, Mobile Operations, Bandwidth Management, ERP, Workflow, Case Study.*

1. INTRODUCTION

COSMOS (COSMOS) originated as an EU-funded research and development project carried out by an international consortium of nine organizations in different European countries. Having been completed in May of 2001, the project produced an integrated system for mobile operations support in the construction industry, focusing on construction sites lacking a permanent network infrastructure. COSMOS' objectives were based on the following considerations: Traditional network infrastructures, systems, and tools are inadequate for frequent and ubiquitous handling of information that is, although centrally stored at the company headquarters, continuously being accessed, generated and updated both at the headquarters and at the construction sites. Operations involve very complex processes at the construction site level, calling for an integrated information system and thus for efficient communication within the construction site itself and between the site and the headquarters. Such communication should be supported from any site location and with different kinds of devices.

The case studies are based on the following scenario: Construction sites are established for limited periods in places where wired telecommunication infrastructure is often unavailable or limited, and so satellite links appear attractive to support the communication between headquarters and construction sites, while terrestrial wireless links are to be used for communication within a site. Moreover, it is vital to improve the enterprise efficiency by means of workflow-based applications, reflecting the company's process flows and supporting team coordination.

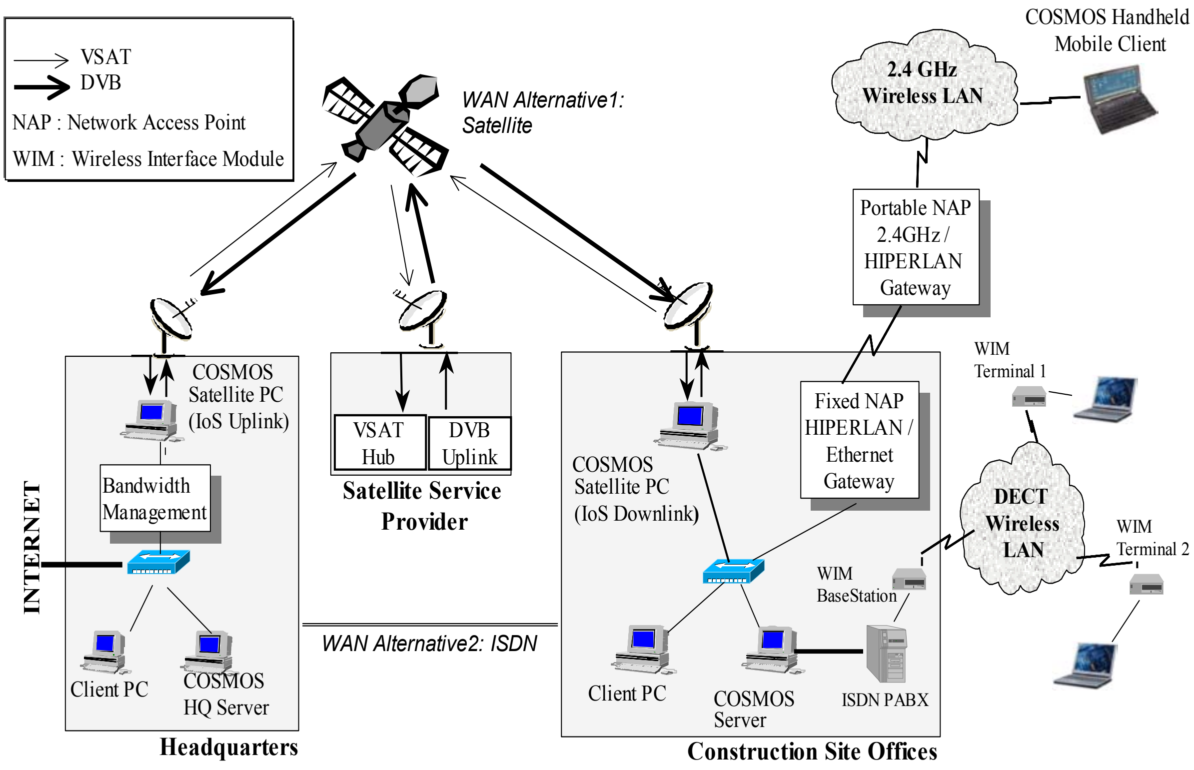

FIG. 1: COSMOS Network Architecture.

Two actual (railway and motorway) construction sites in Italy and Greece were selected for these studies, and this paper presents selected findings from the field work, complemented by a description of the COSMOS system.

At both sites, the full COSMOS system infrastructure was deployed, and two evaluation periods were held. Our objective was to evaluate the system's reliability and performance and to give a qualitative view about the system functionality. During the years 2000-2001, we collected information by means of interviews and questionnaires from the key people working for the construction companies involved. Furthermore, performance measurements were taken with special focus on the COSMOS middleware's bandwidth shaping capabilities.

2. NETWORK ARCHITECTURE

The COSMOS network infrastructure (Figure 1) is IP based and includes a local area network (LAN) at the company headquarters, wireless networks at the construction site, and a hub-based VSAT/DVB satellite wide area network (WAN) link between the headquarters and the site, thereby supporting very remote sites in undeveloped areas. Due to the difficult and ever-changing terrain at construction sites, a two-level wireless network is deployed for intra-site communication, consisting of a specially developed HIPERLAN high-bandwidth long-distance backbone and 2.4GHz ISM-band wireless LAN (WLAN) cells. This allows users to stay connected with the headquarters and site office servers even when using their mobile devices at remote areas of the site. Additionally, our DECT-based wireless network provides for connectivity of portable devices such as warehouse management PCs.

In order to overcome the well-known issues with TCP over satellite links, such as end-to-end packet delay induced data rate reductions without actual congestion, we use a split-connection approach across the satellite WAN, referred to as IoS (Internet over Satellite). Furthermore, as the expensive satellite link constitutes the bottleneck within the COSMOS network infrastructure, active bandwidth management is provided for traffic across this link, thereby supporting priorities for certain data such as real-time video-conferencing traffic or business-critical application traffic (Meissner, Baxevanaki, et al., 2001). As discussed in more detail in section 5, such bandwidth management is carried out by the headquarters and site components of the COSMOS

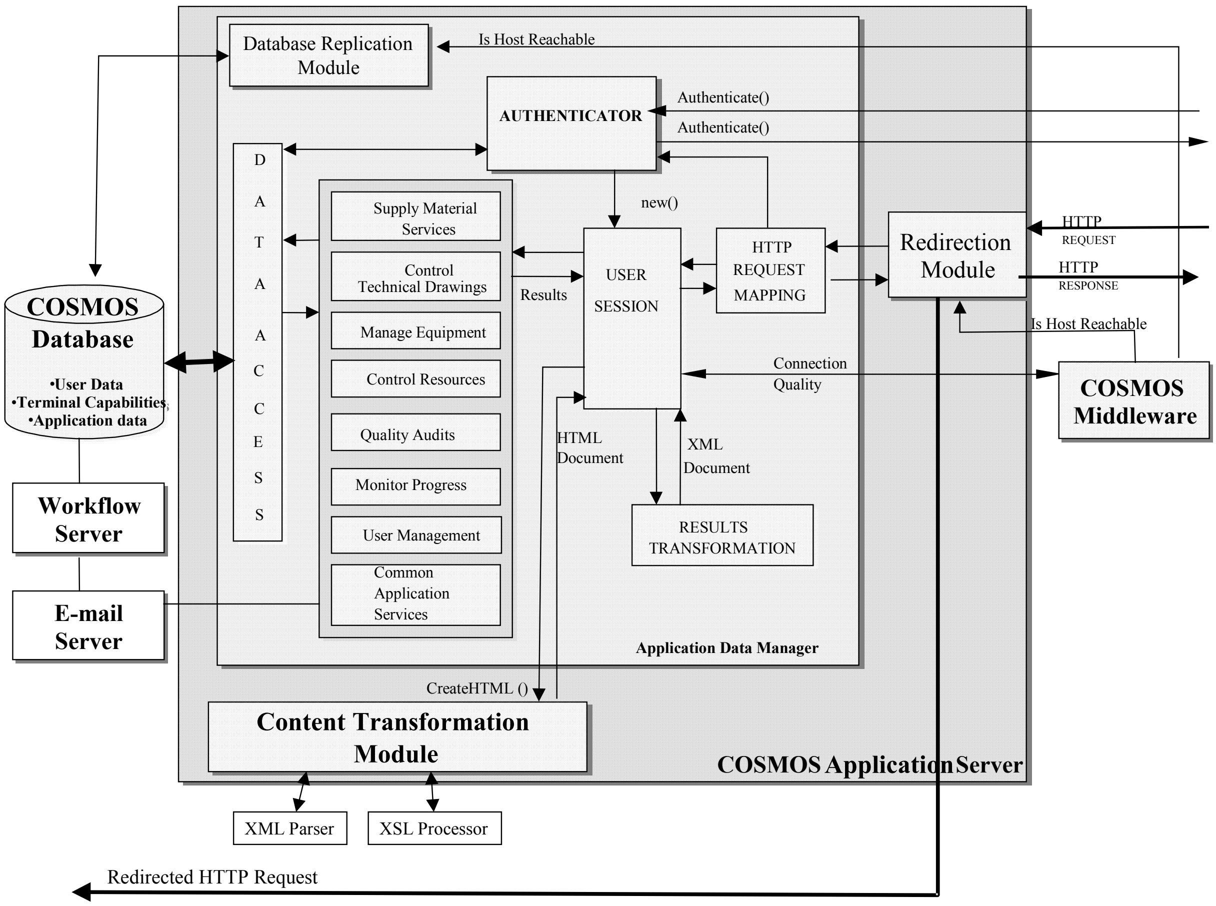

FIG. 2: COSMOS Application Functional Architecture.

middleware as part of its network management features. ISDN is, where available, supported as a WAN alternative.

3. APPLICATIONS

The COSMOS application architecture is designed around a hierarchical application server concept for operation in difficult wireless environments. Application servers (AS) are deployed in a distributed way in the headquarters (HQAS), construction site offices (CSAS), and the mobile clients ("Lite" AS). The HQAS offers the full extent of COSMOS applications, while the CSAS provides less featured versions of all applications, and the Lite AS offers only limited versions of three applications. This distributed architecture allows for offline operation at the site offices (during WAN non-availability) as well as at the mobile clients (when they are outside of WLAN coverage).

All application servers include a web server and thus support HTTP front ends. Additional features are: use of XML for information adaptation based on terminal capabilities, configuration of user access rights and preferences, database access, information synchronization, and redirection of user requests. The application servers interface with the middleware providing site awareness and network monitoring and management.

As shown in Figure 2, we developed six client/server applications for the construction industry: Material/Services Management, Equipment Management, Quality Management, Control Technical Drawings, Monitor Progress, and Control Resources. Their main features are: web access (using any web browser), application access from different types of terminals (desktop PCs to PDAs and WAP-enabled mobile phones), operation over different and heterogeneous network infrastructures, and the capability to use certain application subsets in “offline” mode. All applications are deployed as individual components within the application servers, thus allowing for easy incorporation of additional applications.

4. WORKFLOW SOLUTION

We built a dynamic platform-independent workflow solution to model the company's business processes. The term dynamic workflow (Crowe, Branki, et al., 2000) means here that the elements defined in a workflow process can be dynamically altered to reflect the way instances of the workflow process are actually run. In order to support a large variety of user devices, our workflow is email-based, with a web interface to the company database. Using an email-based solution ensures platform independence, which is the essential criterion in our situation, where many of the client's user devices have only very basic processing capability and therefore, the bulk of the processing must be done at the server side.

The web interface uses server-side processing with Active Server Pages (ASP) that are processed when a workflow HTTP request is made; workflow actions are then triggered in response to user actions, and HTML is sent to the clients. Clients may connect from any construction site being run by the company, or from the LAN in the company headquarters. If these connections are made from a construction site, then access must be made via the WAN link, which is bandwidth controlled by the COSMOS middleware, as discussed in the following section.

The workflow server enforces security in the business processes, ensuring that only certain users have permission to execute certain actions. The workflow engine allows users to work offline using cached data, without being connected to any servers, and then re-synchronize whenever the user re-connects to the rest of the system, processing any actions that may have taken place since he was last online. In the case where different users have made conflicting changes during offline time, the users must decide how to proceed, e.g. by merging, overwriting, or cancelling the changes. In many situations it is also possible to define conflict management rules on the workflow server that will automatically deal with conflicts without the intervention of users.

5. MIDDLEWARE AND BANDWIDTH MANAGEMENT

Network monitoring and management, and thus in particular WAN bandwidth management, are the main responsibilities of the COSMOS components referred to as *middleware*. In this section, we give a functional overview of this middleware and show how it is embedded in the COSMOS system to provide the upper layer application servers with a network resource management interface.

5.1 Functional Overview and Embedding of Middleware

The middleware sits beneath the applications (Figure 3) and serves them as a central arbitration point for their network-related requirements. It is composed of three distinct components running at different device types: headquarters middleware, site middleware, and client middleware.

The headquarters middleware (interfacing to the headquarters application server by means of CORBA) provides client reachability information, along with certain WAN bandwidth and delay data. Its main functionality is managing WAN bandwidth allocation, which is accomplished by using a separate bandwidth management device deployed at the edge of the headquarters LAN. The headquarters middleware also alerts the headquarters application server of upcoming satellite WAN status changes in order to allow for last-minute synchronization.

The site middleware has a similar functionality and design as the headquarters middleware. However, since there is no bandwidth management device at the site, it forwards, via CORBA, any bandwidth control requests to the headquarters middleware for execution. It provides a CORBA interface to the site application server.

The client middleware, typically running at laptops with a wireless network interface card, provides information on host and application server reachability. It performs COSMOS specific site parameter discovery in order to allow the client's application server to reconfigure itself after having entered a new site network.

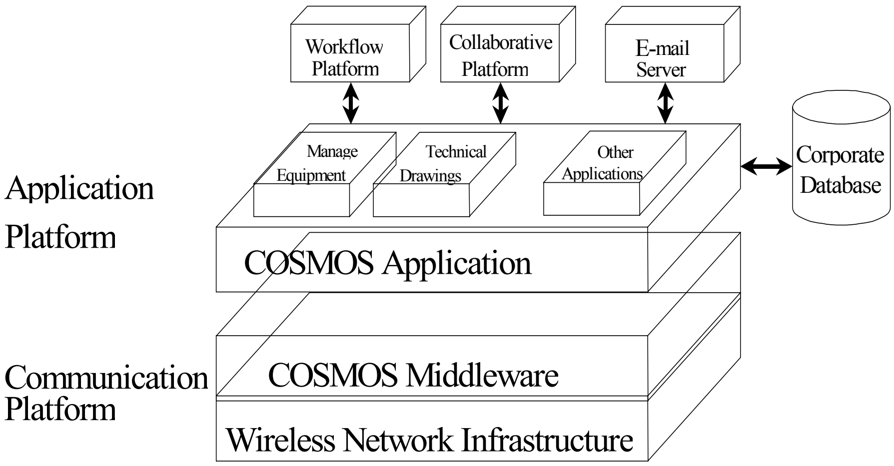

FIG. 3: COSMOS Middleware Context.

5.2 Wide Area Network Bandwidth Management

Between the headquarters LAN and the headquarters WAN gateway we deploy, as shown in Figure 1, a bandwidth management device that is thus in position to intercept any traffic flowing between the headquarters and the site. A Policy Target in the IETF sense (Stone, Lundy, Xie, 2001), this device, a Packeteer PacketShaper (Packeteer), is a specialized third-party appliance that was originally designed to control the flow of TCP/IP packets between an Intranet (or even an individual server) and the outside world. It identifies flows based on different sets of features such as transfer protocol, destination and source, and it performs bandwidth shaping according to associated policies like priority or guaranteed bandwidth. Shaping is accomplished solely by exploiting protocol mechanisms and known properties of the end devices' network stack, and thus by making non-prioritized devices effectively believe that the network they are using has a lower-than-actual bandwidth. Therefore, no protocol stack modifications or other adjustments at end devices are necessary, greatly easing deployment.

These features make the PacketShaper device well suited for COSMOS WAN bandwidth management, however there are a few drawbacks as well. The most serious limitation is the fact that it was designed with the needs of ISPs and static client-server scenarios in mind. It is a standalone appliance that is not originally supposed to be used as a component in an ever-changing, dynamic environment -- it is rather meant to be configured once by a network administrator and then to be left alone in a rack. However, in COSMOS, events such as video conferences are often called on short notice by varying non-expert users from varying hosts, so it is impossible to statically configure a generic "video conference" traffic class. Instead, users must be able to easily trigger on-the-fly network support for their upcoming conference using our GUI (Figure 4). In COSMOS, a CORBA interface was defined for that purpose between the site application server and the site middleware, which is called with the instruction to configure, during a specified time, a proper flow priority for the upcoming conference. The site middleware in turn contacts its headquarters counterpart that finally configures corresponding traffic classes with an associated priority policy into the headquarters' bandwidth management device. Asymmetric settings are also supported in case no video from the headquarters is required. The configuration procedure can also be triggered by a headquarters user by way of the headquarters application server and middleware.

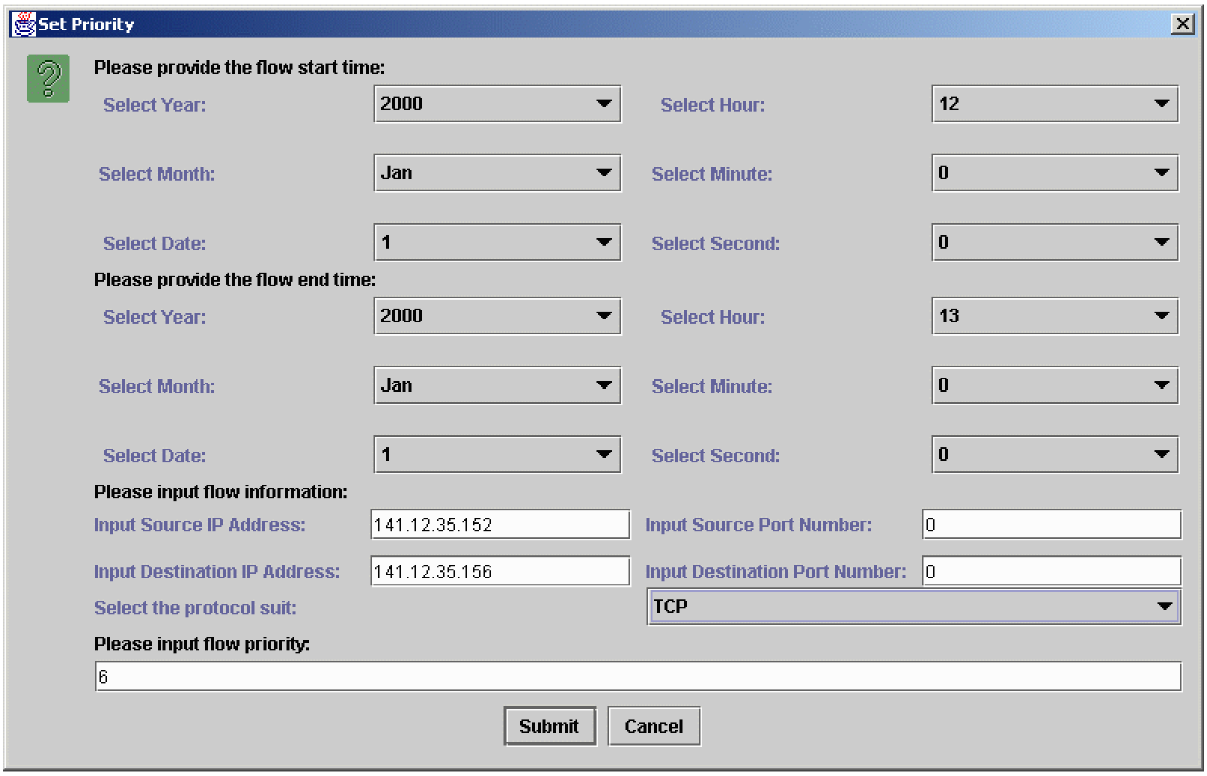

FIG. 4: COSMOS Bandwidth Management GUI.

6. CASE STUDY I: RAILWAY GALLERY

This case study was carried out in two phases at Coopsette, a COSMOS partner construction company, in Italy.

6.1 Case Study Settings

During the first phase of the study, Coopsette's ICT (Information Communication Technology) service documented all the information necessary to maintain and configure the system components; during the second phase, the end-user core evaluation period started. COSMOS was installed at Coopsette headquarters in Reggio Emilia (Northern Italy) and at a railway construction site in Rome (Roma Ostiense Railway Station). The users were asked to measure how the system corresponded to the initial expectations, in particular concerning the Control Technical Drawings and the Monitor Progress applications. The COSMOS infrastructure consisted of the following components: A three-level application server hierarchy (at the headquarters, at the construction site offices, and at the mobile devices for the support of off-line operations), a middleware server, a WAN network (consisting of an ISDN solution - adopted during the whole period - and a VSAT satellite solution adopted during a brief period), a WLAN network (including a Proxim 2.4GHz RangeLAN2, our 5.2GHz HIPERLAN, and our DECT-based solution). Handheld and tablet PCs were used as mobile terminals.

The evaluation was carried out by means of questionnaires distributed to the users, and their feedback was also collected by means of informal communications (emails, phone calls, interviews). Moreover, the ICT service provided various evaluation reports.

With particular regard to the middleware's functionality, assessing the effects of WAN bandwidth management during regular application usage, we measured response times for downloading a complex technical drawing into a CAD viewer simultaneously at three stationary site PCs A, B, C. For downloads via the standard 64kBit/s ISDN WAN link (i.e. from the HQAS), we measured in three test runs with *deactivated* bandwidth management the following download times in minutes (Meissner, Baxevanaki, et al., 2001):

PC A: 13:20, 13:43, 9:41   PC B: 11:33, 12:52, 8:25   PC C: 10:20, 12:45, 8:25.

As in regular application usage scenarios, we did not have exclusive use of the WAN link during the test, which explains some variations from run to run. For a LAN-only setting, i.e. when downloading the drawing from the

CSAS, the download times were between 27s and 59s, thus CAD viewer processing time was determined to be marginal. With *activated* bandwidth management, when C's flows were prioritized across the bottleneck WAN with priority 6 (as opposed to default priority 3), we measured, in two runs, the following download times:

PC A: 9:09, 11:10 PC B: 7:50, 9:28 PC C: 4:36, 5:29

thus yielding a significant performance gain for PC C.

For Microsoft Netmeeting video conferencing between the site and the headquarters, empirical tests showed that perceived video quality improved when priority was assigned to the conference during ongoing application usage.

6.2 Effect on Business Operations

The users expressed that COSMOS was a tool to augment the efficiency, by means of the support offered to the decision-making process, and, moreover, the users considered COSMOS as a means to improve the communications from the headquarters to the construction sites. However, it turned out that the users would have appreciated having higher-performance PDAs, integrating voice and data functionalities. It has to be noted that the demand for such PDAs stemmed mainly from the fact the Coopsette users were especially interested in the Control Technical Drawings application, with the need to display large complex drawings.

Users realized an improvement of efficiency in the business process management, and concluded that COSMOS should eventually integrate other functionalities and that the mobile devices should significantly improve their characteristics. COSMOS met the most important expectations (i.e. having access to information from anywhere and with any kind of device, and supporting decision making), and the COSMOS applications under evaluation during the study received, taking into account the importance and the complexity of the topics involved, a very positive judgment.

7. CASE STUDY II: MOTORWAY INTERCHANGE

COSMOS was installed at the headquarters of Aktor, a COSMOS partner in Athens, Greece, and at a complex motorway interchange construction site of the new Athens ring highway.

7.1 Case Study Settings

The focus of this installation was on three applications: Equipment Management, Supply Material & Services, and Quality Audits. All three levels of the application server were deployed (HQAS, CSAS, Lite AS) along with relevant middleware components. The network infrastructure included a commercial Lucent 2.4GHz WLAN, the COSMOS DECT-based WLAN and a two-way satellite connection. Laptops, rugged PDAs and pen-based tablet PCs were used as mobile terminals. Foremost user requirements were: easier and more immediate communication with site staff (independent of site location with respect to the headquarters) e.g. for on-the-spot problem solving, online monitoring of processes upon need, online updating of information regarding equipment availability and status, and access to data at the site office from the construction site area.

The evaluation of COSMOS by the users was carried out based on a set of evaluation criteria defined by the users in the analysis and design phase. Although issues with the usability of mobile devices by untrained personnel and in direct sunlight conditions were noticed, along with some problems with WLAN coverage in the presence of heavy equipment, COSMOS users were satisfied in terms of the benefits they acquired. User feedback prompted us to introduce new mobile devices.

During the installation phase we suffered from repeated WAN bandwidth and link error rate issues that could only after several days be traced back to an incorrect satellite antenna alignment. The rather high cost of satellite time and the complexity of equipment setup triggered a re-evaluation of satellite vs. ISDN based WAN solutions for construction sites in developed areas, and we found that a satellite link is most suitable where a number of sites have to be connected with each other and to the headquarters at the same time.

7.2 Effect on Business Operations

The use of COSMOS applications changed the way of managing the company's operations in various ways: The Supply Materials & Services application enabled site users to access suppliers and subcontractors historical data and to update the system from the site offices. Equipment Management provided on-site data insertion, and Quality Audits facilitated the execution of on-site audits without the need to carry bulky files to the construction site; facts could be recorded as seen and determined on the spot.

8. CONCLUSIONS AND OUTLOOK

In this paper, we have reported on two case studies we have undertaken for the COSMOS project. From the user feedback we received, it became evident that COSMOS actually helps construction companies to better and more efficiently accomplish their distributed operations, reducing the burden of gathering, processing and forwarding information manually. It has proven to be particularly appropriate to provide an integrated communication and information solution, with customizable client-server applications and network components that are tailored to the requirements stemming from the COSMOS applications. Early user involvement clearly paid off, and users continued to play a driving role throughout the project, giving valuable feedback and prompting various technology improvements.

COSMOS activities have not ended as the research project came to a close. Using as a starting point the Equipment Management application module initially developed in the research project phase of COSMOS, we have now entered the commercialization phase by customizing this module to the requirements of a large Greek construction group where this application is currently in use. Moreover, we are now in a position to support a detailed business planning for the European construction industry, and for the development of additional features in order to offer COSMOS applications as ASP-like web-based services. We also intend to establish closer links to teams having worked on related eWork projects such as ISTforCE (Katranuschkov, Scherer, Turk, 2001) and MICC (MICC).

ACKNOWLEDGEMENTS

COSMOS was supported by the European Union as ESPRIT project EP-27021 within the “IT for Mobility” Thematic Call. Contributing partners were: Omega Generation (Italy), Intracom (Greece), University of Paisley (UK), Fraunhofer IPSI (Germany), Thales (France), Philips (Italy), NDS (UK/Israel), Coopsette (Italy), and Aktor (Greece). This paper is an extended version of (Meissner, Mathes, et al., 2002) providing a more detailed discussion of the COSMOS middleware's network bandwidth management approach (Meissner, Huang, et al., 2001).

REFERENCES

COSMOS: "Construction Site Mobile Operations Support"; EU Project EP-27021; Websites: http://evora.omega.it/~projects/cosmos and http://www.ipsi.fraunhofer.de/mobile/projects

Meissner, A.; Baxevanaki, L.; Mathes, I.; Branki, C.; Bozios, T.; Schoenfeld, W.; Crowe, M. and Steinmetz, R. (2001). "Integrated Mobile Operations Support for the Construction Industry: The COSMOS Solution." The 5th World Multi-Conference on Systemics, Cybernetics and Informatics, SCI 2001, Int. Institute of Informatics and Systemics, July 2001, Orlando, USA, pp. IV/248-IV/255, ISBN 980-07-7544-7.

Meissner, A; Mathes, I.; Baxevanaki, L.; Dore, G. and Branki, C. (2002). "The COSMOS integrated IT solution at railway and motorway construction sites - a case study" In: eWork and eBusiness in architecture, engineering and construction: Proc. 4th European Conference on Product and Process Modelling in the Building and Related Industries, Portoroz, Slovenia, September 9 - 11, ECPM 2002 / Turk, Ziga (eds.); Scherer, Raimar (eds.), European Conference on Product and Process Modelling in the Building and Related Industries. - Lisse (et al.): Balkema, 2002. pp. 623 - 626, ISBN 90-5809-507-X, 2002.

Meissner, A.; Huang, H.; Pommnitz, J. and Steinmetz, R. (2001). "QoS Support for Video Conferencing in the COSMOS System" In: Proc. Multimedia Technology and Applications Conference (MTAC 2001), University of California, Irvine/CA, USA, Nov. 7 - 9, IEEE Computer Society, USA, pp. 178 - 184, 2001.

Packeteer Website: http://www.packeteer.com/prod-sol/

Stone, G.N.; Lundy, B. and Xie, G.G. (2001): Network policy languages: a survey and a new approach. IEEE Network, Vol. 15(1), Jan.-Feb. 2001

Crowe, M., Branki, C., McGlinchey, S., Biegus, L., Kydd, S. (2000). “Agent-Supported Workflow Systems”, Proceedings of SEID 2000.

Katranuschkov, P.; Scherer, R. J.; Turk, Z. (2001): „Intelligent Services and Tools for Concurrent Engineering – An Approach Towards the Next Generation of Collaboration Platforms”, ITcon special issue, Zarli, A. & Rezgui, Y., guest eds., Dec. 2001, http://www.itcon.org/2001/9

MICC: EU ACTS AC088 Project MICC – “Mobile Integrated Communication in Construction”; Website: http://www.cordis.lu/infowin/acts/rus/projects/ac088.htm