Demonstrating Wireless IPv6 Access to a Federated Health Record Server

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Abstract. This paper describes the practical implementation of a federated health record server based on a generic and comprehensive architecture, deployed in a live clinical setting and accessed from wireless and IPv6 network test-beds. The authors, working at the Centre for Health Informatics and Multiprofessional Education (University College London), have built up over twelve years of experience within Europe on the requirements and information models that are needed to underpin comprehensive multi-professional electronic health records. The UCL federated health record server is running in the Department of Cardiovascular Medicine at the Whittington Hospital in north London. Through the EU 6WINIT project this infrastructure has been modified to enable secure wireless access via IPv6.

1   Research and Development in Electronic Health Records

Realising the electronic health record has been at the heart of the EU Health Telematics Framework Programmes. Considerable research has been undertaken to explore the user requirements for adopting EHRs (e.g. published by the GEHR [1-5] and EHCR Support Action projects [6]), resulting in architecture formalisms to capture healthcare data comprehensively and in a manner which is medico-legally rigorous and preserves the original clinical meaning, (e.g. GEHR and the CEN standards ENV12265 [7] and ENV13606 [8]). These results recognise that personal health data is often very sensitive and always to be regarded as confidential.

Other research has identified the requirements to support the communication of EHRs within federated communities of healthcare enterprises to support shared patient care across sites (the Synapses project [9-11]) and middleware architectures to integrate across R&D projects (SynEx [12]). Outputs from these projects have recently been consolidated within a PhD thesis based on the UCL demonstrator [13].

More recently parallel threads of research in Europe and Australia have been united through the openEHR Foundation. This Foundation is an independent, not-for-profit organisation and community, facilitating the creation and sharing of health

records by consumers and clinicians via open-source, standards-based implementations (see www.openehr.org).

A new European (CEN) standard is presently being developed to define the way in which clinical and EHR systems can interoperate to exchange patient records in a systematic and medico-legally sound manner. This work, drawing on thirteen years of European R&D, is being undertaken in close working relationship with openEHR and with HL7 [14].

UCL Information Architecture

The Synapses approach to distributed healthcare records applied the methodology of database federation to a standard and comprehensive schema, the Federated Healthcare Record (FHCR) information architecture, mediated and managed through a set of middleware services [11]. This has required a scalable model for representing any conceivable health record information, created by any profession, speciality or service, whilst recognising that the clinical data sets, templates etc. will be diverse, complex and will change frequently as clinical practice and medical knowledge advance.

A dual model approach has been adopted, which distinguishes a Reference Model, used to represent the generic properties of health record information, and Archetypes (conforming to an Archetype Model), which are meta-data used to represent the specific characteristics of the various kinds of clinical data that might need to be represented to meet the requirements of each particular profession, speciality or service. The Reference Model represents the global characteristics of health record entries, how they are aggregated, and the context information required to meet ethical, legal and provenance requirements. Archetypes each define (and effectively constrain) legal combinations of the building-block classes defined in the Reference Model for particular clinical domains and contexts by specifying particular record component names, data-types and prescribed value ranges, and values.

2   Federated Health Record Middleware Services

The federated health record (FHR) components are delivered via a set of middleware services that enable a requesting service (e.g. a client clinical application, or another middleware service such as a decision support agent) to access electronic health record information from a diversity of repository servers (feeder systems). The feeder systems may be on-site at an institution or connected remotely through telecommunications services. These actions take place in accordance with the user's role-based privilege and are registered in an access audit trail. The London demonstrator is utilising the following UCL-developed component services:

Federated Health Record services: a scalable run-time FHR environment supporting distributed access to record components from new and legacy feeder systems.

Archetype Object Dictionary Client and services: a means of facilitating feeder system sign-up, of mapping each feeder system schema and of navigating the federation environment.

Persons Look-up services: storing a core demographic database to search for and authenticate staff users of the system and to anchor patient identification and connection to the patient's federated healthcare record.

Expert Advisory (Decision Support) services: for anticoagulation management, to calculate the patient's next treatment regimen and next monitoring interval. This service is provided through specific agents called from a dedicated client and these return data to this client.

Web-based applications: to provide end-user clinical views and functions.
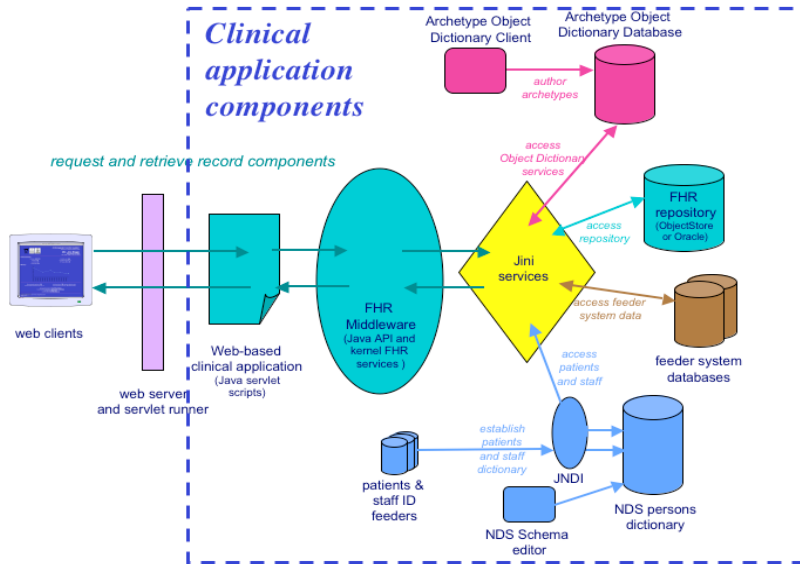
Fig. 1. Core FHR components handling the request for and retrieval of patient records

All of the main components are written in Java, and are deployed within a middleware environment managed through Novell Directory Services and JINI, an open standard service-integration technology. This overall approach will allow the ongoing development of flexible and portable applications with high-level graphical user interfaces to be made where such applications can inter-operate across diverse architectures and infrastructures. New web-based clinical applications have been written using Java servlets to provide end user access to the patient records held within the FHR server. Further details of this information architecture and implementation may be found in [13, 15].

3   The 6WINIT Project

The IPv6 Wireless internet INITiative (6WINIT) project (2000-2002) was a European IST Framework V initiative involving telecoms companies, equipment manufacturers, solutions/software providers, universities and hospitals. Its objectives were to validate the introduction of the new mobile wireless Internet in Europe, based on a

combination of the new Internet Protocol version 6 (IPv6) and the new wireless protocols (GPRS and UMTS). The UCL north London demonstrator was one of three 6WINIT clinical sites. 6WIND and IABG provided most of the wireless and IPv6 components used in this demonstrator. These were installed and configured locally by the Computer Science department of UCL.

IPv6 Transition Mechanisms (tunnelling). Native IPv6 services from the main application server were tunnelled via IPv4 from CHIME (north London) to Computer Science (central London) using UCL's main University Intranet. The 6WIND IP Edge Device implements the v4-v6 migration mechanisms over a dual stack entirely developed by 6WIND. An Edge device was configured and installed at CHIME, and another at UCL Computer Science.

Security Mechanisms. A virtual private network (VPN) was required to provide an authenticated and encrypted channel of communication between the clinical applications server and the end-user specifically supporting the use of mobile devices connected via wireless LAN, GPRS or UMTS. The IABG Road Warrior was installed and configured to provide a VPN extension to mobile users based on IPsec, using a Linux client for the mobile user and the 6WINDGate as an IPSec gateway.

Certificate-based key management. The CHIME clinical applications were adapted also to communicate with a certificate server at UCL Computer Science (developed by University of Murcia).
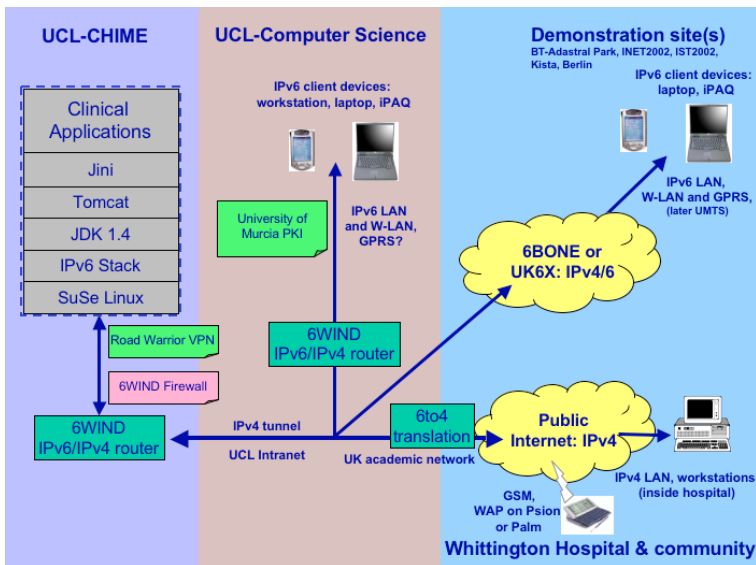

Fig. 2. Network architecture of the London demonstrator site

Figure 2 above shows the principal clinical application (health record) services, located at CHIME, being delivered via an IPv6 stack infrastructure, sent to UCL Computer Science and routed forward to the public Internet and to new IPv6 networks (6BONE or UK6X). The communications pathway involves the use of some IPv4 networks, such as the UCL Intranet connecting CHIME in north London to Computer Science in central London, and the public Internet. IPv6 access to the CHIME FHR

services and clinical applications has been validated from central London (WLAN), Ipswich (WLAN and GPRS, provided by BT), Berlin (GPRS, provided by DTAG) and Kista (UMTS, provided by Ericsson).

4   North London Demonstrator Setting

The north London demonstrator at which the UCL FHR services and clinical applications are being evaluated comprises: the Department of Cardiovascular Medicine at the Whittington hospital, 2-4 community-based cardiology clinics, Several GP practices and community pharmacies in north London and patients managing their own healthcare at home. The north London demonstrator vision is to deliver the seamless shared care of patients with cardiovascular illness, in a managed care environment. The clinical applications so far in use are summarised below.

Anticoagulant Application

This application provides a set of HTML web clients to enable the management of anticoagulation therapy by clinical staff (or patients). The system incorporates drug dosing decision support and recommends monitoring intervals between blood tests. It has been used daily by staff at the Whittington Hospital since summer 2000, running clinics with up to 120 patients per day. It is also accessed from outside the hospital by two community pharmacists, and it is hoped to include other pharmacists, GPs and patients as users in the near future.

Fig. 3. Anticoagulant client - viewing a clinic contact

Rapid Access Chest Pain Clinic (RACPC)

This application provides clinicians working both inside and outside the Whittington hospital with access to the record of patients having non-acute or sub-acute chest pain (i.e. possible heart disease) symptoms. The primary clinical application has been hosted on the same FHR server as the anticoagulant system, and shares the same core middleware services. The application has been running live for nearly one year, and is being used by nurse specialists providing a Rapid Access Chest Pain Clinic service and a heart failure assessment service within the hospital and at patients' homes.

Fig. 4. RACPC client – viewing cumulative physical examination data

5   Conference and Technical Review IPv6 Demonstrations

Four proof of concept demonstrations of the 6WINIT infrastructure and clinical applications were made during the project:

- 2 technical reviews including Ericsson's IPv6 test bed in Stockholm;
- 2 international conferences: INET 2002 (Washington DC) and IST 2002 conference in Copenhagen.

These demonstrations have been documented in project deliverables and reports (available from http://www.cs.ucl.ac.uk/research/6winit). The IST conference in Copenhagen (November 2002) provided a valuable end-to-end validation of the reliability of connection, the network performance and security. Although the IPv6 wireless access point was serving several simultaneous IPv6 Cluster demonstrations, each web screen downloaded from London within about half a second. There were no timeout problems or periods of inaccessibility, and the scaling, resolution and performance of the Compaq iPAQ (adapted for IPv6) was excellent.

Ideally the UCL team had hoped to be able to deploy the validated 6WINIT infrastructure in Whittington Hospital. This was not possible, due to the requirements for the hospital to comply with national NHS and local vendor policies. Nevertheless, the Department of Cardiovascular Medicine managed to deploy several elements of the infrastructure on to internal departmental network. In practice this has meant an

IPv4 clone of the applications, web server, JINI and FHR services. It has not been possible to deploy the 6WIND edge device or the Road Warrior within the department. However, the view of the authors is that the demonstrations given, for example at IST 2002, are a realistic vision of what is both clinically valuable and technically acceptable for future distributed health care.

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