Design of a web service based prototype appointment system for improving the patient access to primary health care service

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Design of a Web Service Based Prototype Appointment System for Improving the Patient Access to Primary Health Care Service

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DECLARATION

I, Hongxiang Hu, declare that this thesis, submitted in fulfilment of the requirements of the award of Master of Information and Communication Technology by research, in School of Information Systems and Technology, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualification at any other academic institution.

Signature: _____

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ABSTRACT

Research Aim and Questions: This research aims to develop a computer-based appointment system, which could integrate with the existing clinical information system and improve the patient access to the services offered by both General Practitioners (GPs) and Allied Health Professionals (AHPs) in a primary health care clinic Centre Health Complex (CHC). To achieve this requires the development of an understanding of the features and processes of patient booking in the primary health care environment; the identification of the gaps of the existing patient booking system; and a scheme of an improved system, which could fill these gaps. The output of this project is a prototype of patient appointment system built on web service technology.

Research background: To acquire a routine appointment from a GP or an AHP, a patient may need to wait more than several weeks in CHC. Patient's long waiting time is always accompanied with some series access problems such as missed appointments in the practice. Consequently, some patients are driven from primary health care to Emergency Department (ED) and add pressure to the overburdened hospital system. The patient's access problem is initiated by the traditional appointment system, which is based on a basic fixed schedule for booking patients. It does not record a patient request if the request is not met; therefore, it has missed the essential baseline data about the patient's actual demands. Without this information, the practice could not plan effectively to fully meet the demands of the patients for primary care services.

Research Methodology: This research followed a standard software development process – waterfall model. Three phases of study were carried out, including (1) requirement analysis, (2) system design, and (3) prototyping and unit testing. First, a filed study was conducted in the CHC to collect information about the features and processes of patient booking and the IT infrastructure in the clinic. The weakness of the practice workflow and the IT infrastructure were identified. Then the design of the new appointment system was proposed to plug these gaps. Finally, a prototype of the proposed appointment system was built.

Result and Conclusion: This design and prototype appointment system was influenced by the general idea of the Advanced Access (AA) model. Its workflow was developed following the general process of AA: (1) setting up the access target; (2) monitoring the patient's demand; and (3) planning the provider's supply to meeting patient's demand. The proposed appointment system was composed of four modules as: Request module, Schedule module, Performance module and Strategy module. The role of each module was to manage patients' appointment requests, manage the providers' supply, monitor practice performance and provide clinic recommendations for taking appointments respectively. In order to be compatible with the existing IT infrastructure, this appointment system was built on web services technology, so that both GPs and AHPs could benefit from the inventive management process and integrated interface.

Future Direction of This Project: Due to the time limit, the implementation and evaluation were not conducted for this project. The prototype appointment will be implemented in CHC in the future, when the new features we have designed for this appointment system for improving patient access will be tested and justified.

PUBLICATIONS

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.NET	Dot Net
AA	Advanced Access
AHP	Allied Health Professional
AIHW	Australian Institute of Health and Welfare
APCC	Australia Primary Care Collaborative
AR	Appointment Redesign
AROS	Access Response Index
ARPN	Assign Roles to Practice Nurse
CCM	Chronic Care Model
CDM	Chronic Disease Management
CHC	Centre Health Complex
CIS	Clinical Information System
DC	Domain Controller
DoHA	Department of Health and Aging
DPA	Deny Prescheduled Appointment
ED	Emergency Department
EPC	Enhanced Primary Care
E-R	Entity-Relationship
GC	Group Consultation
GP	General Practitioner
ICIC	Improving Chronic Illness
IPSS	Increase Provider Standard Session
IPW(H)	Increase Provider Workload (use optional hours)
IPW(S)	Increase Provider Workload (use extra sessions)
LINQ	Language-Integrated Query
NHS	National Health Service
OS	Operating System
RNP	Restrict New Patient
RP	Recruit a Physician
RPA	Restrict Prescheduled Appointment
RTP	Recruit a Temporary Physician

RWJF	Robert Wood Johnson Foundation
SDLC	Software Development Life Cycle
SDOP	Shift Demand to Other Providers
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol
SSH	Secure Shell
TC	Telephone Consultation
UDDI	Universal Description Discovery, and Integration
UML	Unified Modelling Language
WSDL	Web Services Description Language
XML	Extensible Mark-up Language

1. INTRODUCTION

1. 1 Background

Population ageing has been one of the major demographic changes in this century. In Australia, the older age group are the largest users of medication (Australian Pharmaceutical Advisory Council 2002). This will cause increased financial expenditure and insufficient aged care facilities for the coming 50 years (Productivity Commission 2005; Department of Health and Aging 2007). It is imperative to continuously improve the capacity of health care services in coping with the increasing demand for care by the ageing population in medication management (Australian Pharmaceutical Advisory Council 2002). To achieve that, collaborative health care services for improving the patient's chronic disease management were introduced (Dennis, Zwar et al. 2008). These services can provide complex, high quality and multi-discipline care from a wide range of service providers to patients who have chronic disease. Besides, information technology based health solutions that enhance information exchange among patients, care providers, community facilities and government departments are important enablers for improving medication management (Yu and Soar 2003).

The Australian government Department of Health and Aging (DoHA) introduced the Enhanced Primary Care (EPC) program in 1999. This program is generally implemented by General Practitioners (GPs) and Allied Health Professionals (AHPs). The significance of this program is that it enables different health care providers to offer multidisciplinary services as a delegate team working on their patients. Although the EPC program offers patients the access to the multi-disciplinary services, it is a challenge for the different health care providers to sustain the

efficiency of patient access. Reasons include that the introduction of the EPC program has caused new challenges to the traditional isolated clinical information systems (CIS) that are not capable of sharing information with each other, and the provider's long waiting list has prevent the patient from getting timely access to the services.

In 2008, a master's level research project was carried out in a multi-disciplinary clinic: the Centre Health Complex (CHC) in Shellharbour (Shellharbour is a semi-rural area on the south coast of New South Wales with a population of 66,905 in 2009). The original goal of the study was to investigate how to integrate the CIS in a primary care clinic. The design of a web-service based appointment system to improve patient's access to the health care services was identified as the research focus for this research project.

1. 2   Statement of the Problem

The CHC is a representative example to a big multi-disciplinary medical centre in Australia. Various health care providers are co-located in this medical centre to provide complex services to the nearby communities. A range of computer equipments and telecommunications applications has been implemented in the centre to facilitate the provision of health care services. Health care providers in different specialties choose different applications to facilitate their daily practice. This means that the software used by GPs may not meet the requirements of allied health care professionals.

There are two major challenges identified in CHC for the provision of patient-centred health care: one is that the practice lacks effective methods to manage patients' access; and the other one is that the existing CIS lacks the ability to share information amongst different health care providers.

The first challenge is caused by the fact that the traditional carved-out appointment model is only a tool to match patient requests with the provider's schedules. It is not designed for access management. Once there is a burst of request, a service delay would appear. A patient may have to wait for more than a few weeks to get a routine appointment. In addition, the EPC program requires a patient to see some other providers through multiple visits. Because service delays occur at every visit, the accumulated delay of health care services would be extended much longer than that to be expected by the provider. This will eventually hamper the quality of care.

The other identified challenge related to the isolated CIS used by different health care providers. Although, increased use of computer-based applications and systems have brought great advantages to health care providers, many of them are costly and do not allow data exchange between service providers in different specialties. This is because these computer-based applications are built up on different structures, in different operating system, and using different programming language. Even were placed in the same building, these applications work as isolated data islands and have very limited capacity for information sharing.

1. 3   Research Objectives

The primary objective of this research was to design a booking system that could integrate the existing systems and improve responses to patient request to access both GPs and Allied Health Professionals in CHC. As CHC is a typical medical centre in Australia that provides multi-disciplinary healthcare to patients, this solution is also applicable to other medical centre with a similar service structure.

To achieve this, three key research questions were proposed. Each of these questions has been further subdivided into a number of sub-questions:

Question 1: What do GPs, AHPs and patients do during the patient booking process?

1.1 What is the traditional appointment model?

1.2 Who are the actors and what do they do in the appointment booking process in CHC?

Question 2: What is the weakness of the current patient booking system?

2.1 What are the problems with the traditional workflow of the patient booking process?

2.2 What are the problems with the current appointment system?

Question 3: How can a new computer-based booking system be designed to fill the gaps of the current patient booking system?

3.1 What is the new appointment model that can be implemented to improve patients' access?

3.2 How to design a new appointment system which can support the implementation of the new appointment model?

3.3 How to ensure that the new appointment system would be supported by the existing CIS infrastructure used in CHC?

1. 4   Significance of the Research

The research contribution of this project is to provide a new design of web service appointment with potential to improve patients' access to primary health care services. As most Australian medical centres have shared a similar structure, this solution has the potential to be extended to the other sites, especially those sites where there is a shortage of health care providers.

This thesis also proposed a model for an appointment system with the potential to facilitate the integration of booking processes between GPs and AHPs based on the existing IT infrastructure. The implementation of this model would increase the possibility of improving patient-centred care by the medical centre CHC through

improved access to information from different members of the multi-disciplinary health care teams.

1. 5   Research Methodology and Research Design

Since the goal of this research is to design a computer-based application, the waterfall model of the software development life cycle (SDLC) has been adapted. This process includes five steps (1) requirement, (2) design, (3) coding and unit testing, (4) system Integration, and (5) operation and maintenance. It starts as an idea and progresses until this idea germinates and dies when it is concluded (Keyes 2003). Due to the time limit, this research has accomplished the first three of five steps: the following section will briefly explain the design of each phase.

1.5.1   Phase 1: Requirement Analysis

We adapted three research methods in research Phase 1 as: data collection and analysis, field study and use case analysis. All of these three methods were applied to guide the development of detailed requirements for the appointment system data collection and analysis, reviewing the existing publications on the related field to identify the common problems and related solutions. The field study was conducted to gain an understanding of the patient booking process in the clinic where this research has been undertaken. Workflows that users follow in the appointment booking process were documented in this phase.

1.5.2   Phase 2: System Design

System modelling and web service approach were the two approaches used for system design. Modelling was a major approach to describe the structure of the

proposed appointment system. The web service approach was applied to ensure that the proposed appointment system would be compatible with any operating system.

1.5.3   Phase 3: Prototyping and Unit Testing

Research Phase 3 involved prototyping and unit testing. In this phase, a sample application from the model of the system was built. Microsoft .NET framework was adapted as the Programming environment. The package for unit testing, which was applied as a testing method, was enclosed in the Software Development Kit of Visio Studio 2008.

1. 6   Thesis Outline

This thesis consists of eight chapters. Chapter 2 reviews the literature related to the appointment system extensively, including the Australian Enhanced Primary Care (EPC) Program, the Advanced Access model and concerns in developing an appointment system. Chapter 3 outlines the research methodology, the process of study and justifies the suitability of the selected research methods. After that, Chapter 4 presents the results of field study, followed by the discussion of the weakness of the existing appointment and IT infrastructure in Chapter 5. Chapter 6 presents the design of the appointment system, which integrates the existing IT infrastructure and has the potential to improve the patient's access and cooperate with the existing IT infrastructure. Chapter 7 presents the system prototyping and unit testing. Finally, Chapter 8 concludes the study, addresses its limitations, and outlines the future research directions.

2. LITERATURE REVIEW

2. 1 Introduction

This chapter will discuss the issues of concern to the research topic. Section 2.1 presented the background of Australian primary health care from two perspectives: health care providers and insurance. Section 2.3 addressed the needs of collaboration among different health care providers to face the challenge of chronic disease management caused by the population aging. These two issues highlight the position of patient admission in Australian primary health care and the barriers, which hampered patients' timely access to primary health care, are reviewed in section 2.4. After this, section 2.5 reviews the appointment models extensively. A brief review of critical issues in designing an appointment system is provided in section 2.6, even though studies suggest that the research on designing computer based appointment systems is limited. These issues include: revealing patients' demand; evaluating service performance and managing clinic supply.

2. 2 Health Care System in Australia

In order to understand the significance of patient admission in the primary health care in Australia, some background discussion relating to the Australian health care system is presented in this section. This pattern includes the structure of health care provision involved in patient care and the role of health insurances shaping the systemic flow within the healthcare environment.

2.2.1   Health Care Providers

In Australia, health care services are provided at two levels: primary health care and acute health care. Primary health care is performed by General Practitioners (GPs),

nurse and allied health professionals, and acute health care is usually provided by a specialist. In general, GPs play a central role to in managing patients' demographic health; specialists focus on the patients' complex illnesses and provide advice to GPs; and AHPs act as supplementary actors providing non-medical services.

General practice is the first point of contact for the majority of people seeking health care, and often therefore the first point of referral. In the provision of primary care, much general treatment is seen; the General Practitioner often deals with problem complexes rather than with established diseases (Royal Australian College of General Practitioners 2005). The Role of General Practitioner is summarised by Strasser (1991) so-called 3P's and 3 C's: provision of primary care, preventive care, patient-centred care, continuing care, comprehensive care, and community-based care to individuals and their families .

It has been said that the GP focused on the person and seek to understand the person and context of disease, and the specialist would have a better understanding of the disease process and current management, especially for complex conditions (Piterman and Koritsas 2005). Specialists are defined by their expertise in relation to a particular part of the body, disease or group of diseases and by procedures or interventions they may carry out in relation to these diseases or systems; they act as consultants, that is, they give advice to GPs who may carry on the management after the patient leaves the specialist. The specialist's care of the patient may therefore be episodic rather than continuing, although some specialists often inappropriately take on the role of providing continuity of care for chronic and stable conditions, for example hypertension, ischemic heart disease and non-insulin dependent diabetes (Piterman and Koritsas 2005). This can diminish the available time for consulting on new problems or lengthen waiting time for such appointments.

Allied health professionals belong to clinical health care professions distinct from medicine, dentistry, and nursing. They work in a health care team to make the health care system function. Allied Health professionals are involved with the delivery of health or related services pertaining to the identification, evaluation and prevention of diseases and disorders; dietary and nutrition services; rehabilitation and health systems management, among others. Allied health professionals, to name a few, include dental hygienists, diagnostic medical sonographers, dieticians, medical technologists, occupational therapists, physical therapists, radiographers, respiratory therapists, and speech language pathologists.

The majority of doctors are self-employed. For some allied health/paramedical professions, there is a significant proportion self-employed. Others are mainly employed by state and local government health organisations. Specialists usually work in private and/or public hospitals and care for their acutely ill patients in these settings (DoHA 2000).

2.2.2   Health Care Insurance

The major part of the national health care system is called 'Medicare'. It maintains high quality health care which is both affordable and accessible to all Australians, often provided free of charge at the point of care (DoHA 2000). As the Australian universal health insurance, Medicare covers fees for in-patient services as well as out-patient services (Medicare 2009). Even though, Medicare benefits are payable to both public and private hospital services, certain services have been excluded for the Medicare benefit, such as accommodation, and require patients to purchase private health insurances as supplementary coverage to pay for their special health care needs (DoHA 2000).

Medicare Australia (known as the Health Insurance Commission before Oct 2005) has established a referral system to organise health care services, similar to UK, Canada, and parts of Europe, for the purpose of preventing unnecessary specialist service and cost containment (Arlyss Anderson and Edward 2003). It enshrines the role of the GP as the gatekeeper to the health system and patients are required to see a GP in order to be referred to a specialist (Piterman and Koritsas 2005). If these requirement are not met, either no benefit is payable or the benefit is lower.

For most pathology and diagnostic imaging services, Medicare benefits are paid only when another doctor has referred the patient to the doctor providing the pathology or imaging service. These requirements are in place in order to constrain costs by removing financial incentives to obtain unnecessary specialist services. As a consequence, most access to specialist medical services is on referral from General Practitioners (DoHA 2000).

2. 3   The Need for Collaboration

The Australian Institute of Health and Welfare (AIHW), the country's national health and welfare statistic agency, published two reports in 2001 and 2006, addressed the serious issues of chronic disease and associate factors in Australia. In these reports, Chronic diseases — conditions such as heart disease and diabetes that tend to be long-lasting and persistent in their symptoms or development — are a major health concern in Australia and other developed countries, placing great burden on individuals, communities and health. The top ten causes of disease burden in Australia are chronic diseases and it is estimated that in 1996 all chronic diseases and conditions were responsible for 80% of the total burden of disease, mental problems and injury, as measured in terms of disability-adjusted life years (AIHW 2006). By 2016, an estimated 16% (3.5 million) of Australian population will be experiencing

the effects of chronic disease (AIHW 2002). Diabetes Australia estimates that –
unless a concerted effort is made on individual and societal levels to decrease risks –
by 2010, there will be 1.8 million Australians suffering from diabetes. The estimated
future cost to the Australian health system is enormous, reaching $1.2 billion
annually (Grimmer-Somers, Dolejs et al. 2008). The 2006 AIHW report also
indicates that the chronic diseases are serous drain on the recent health system, they
accounted for the nearly 70% of the health expenditure that can be allocated to
diseases (AIHW 2006).

Confronted with problems with respect to chronic disease management (CDM), the
need for closer inter-professional cooperation has never been greater (Piterman and
Koritsas 2005). Improving Chronic Illness Care (ICIC), a national program of the
Robert Wood Johnson Foundation (RWJF), was launched in 1998 to test the utility
of Chronic Care Model (CCM) (Known as Wagner's model) in quality improvement.
ICIC (2009) ascribes the major deficiencies within the CDM as:

- Rushed practitioners not following established practice guidelines

- Lack of care coordination

- Lack of active follow-up to ensure the best outcomes

- Patients inadequately trained to manage their illnesses

The Wagner's Chronic Care Model is a guide to solve the deficiencies and achieve
higher-quality CDM within primary care. This model is composed of six interrelated
components: self-management support, clinical information systems, delivery system
redesign, decision support, health care organisation and community resources. It can
produce system reform in which informed, activated patients interact with prepared,
proactive practice teams (Wagner 1998)(see Figure 2-1 next page).

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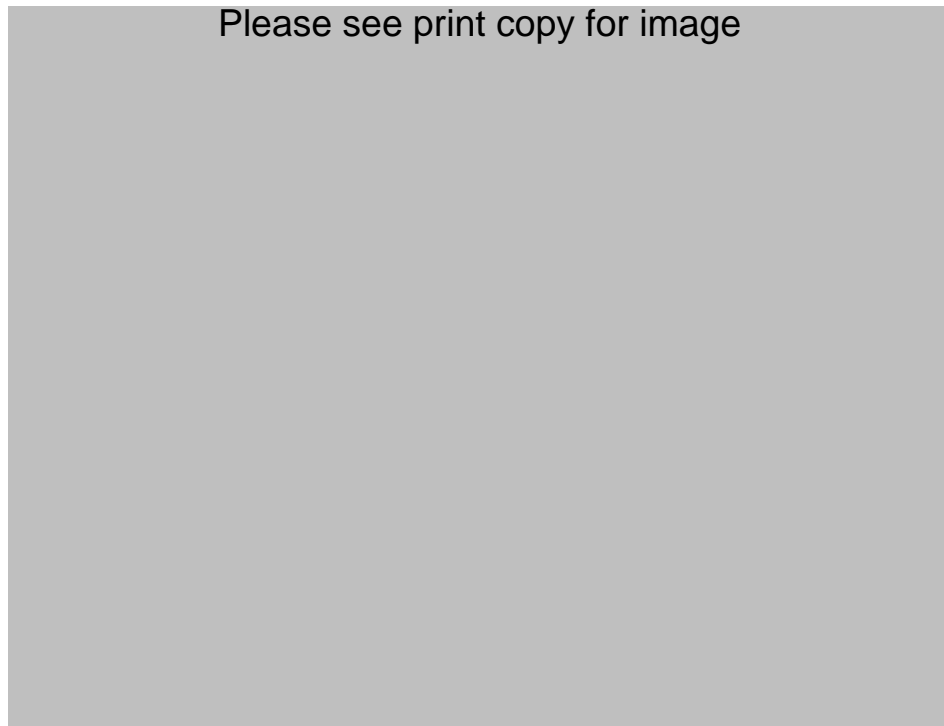
Figure 2-1: Wagner's Chronic Care Model Provided by Improving Chronic Illness

Care (ICIC)

This model suggests that the patient-provider interactions resulting in care that improves outcomes are found in health systems that:

- have well-developed processes and incentives for making changes in the care delivery system;

- assure behaviourally sophisticated self-management support that gives priority to increasing patients' confidence and skills so that they can be the ultimate manager of their illness;

- reorganise team function and practice systems (e.g., appointments and follow-up) to meet the needs of chronically ill patients;

- develop and implement evidence-based guidelines and support those guidelines through provider education, reminders, and increased interaction between generalists and specialists; and

- enhance information systems to facilitate the development of disease registries, tracking systems, and reminders and to give feedback on performance (Wagner 1998).

Enhanced Primary Care (EPC) program, introduced in 1999, is one of a range of initiatives aimed at improving prevention and management of chronic disease in Australia. This program is consistent with the Wagner's CCM in GP centred collaborative health care (Foster, Mitchell et al. 2008). According to the regulation from Department of Health and Aging (2008), patients who have a chronic condition and complex care needs that are being managed by their GP under an EPC plan may be eligible to receive the Allied Heath Care. This care includes features, such as:

- Patient must have an Enhanced Primary Care (EPC) plan prepared by their GP

- GP refers to allied health professional

- Allied health professional must report back to the referring GP

**Individual allied health services under
Medicare Chronic Disease Management items**

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Figure 2-2: Flow diagram of individual allied health services under Medicare

Chronic Disease Management items (DoHA 2004)

In 2004, DoHA (2009) introduced chronic disease management plans as a subset of the EPC program. CDM was involved an all allied health care services for patients with chronic disease. A typical workflow for a patient to acquire Allied Health Care is shown in Figure 2-2:

As a precondition for Allied Health Care, the GP is in charge of the patient's referral to the allied health care services and should be involved in and monitoring the

patient's treatment results. Thus, a written report is required after the first and last service to the allied health professionals. These written reports should include any investigations, tests, and/or assessments carried out on the patient, any treatment provided and future management of the patient's condition or problem.

The GP centred collaborative framework has been established under the EPC program; however, the clinical information system has not been built up to support the collaboration between multi-disciplinary providers. The linkage among those involved providers remains loose (Blakeman, Zwar et al. 2002; Cant and Aroni 2007; Martin and Peterson 2008), which suggests a well-structured CIS model help to overcome the problem.

2. 4   Problems of Patient Admission in Primary Health Care

The health care system in section 2.2 and 2.3 discussed the background of the primary health care in Australia. In regard to the role of general practice, the capacity of health care services, to some extent, is determined by the patients admitted in the general practice setting in Australia. However, there are many problems with the patients' admission.

Service delay is an obvious problem, which is caused by the lack of clinic resources when patients request for access to their GP has been postponed in the future. This problem is of significant concern in Australia (Greco, Sweeney et al. 2001) as well as other parts of the world (Murray and Tantau 1998; Camacho, Anderson et al. 2006). Unlike the UK where country wide statistics about patient waiting and satisfaction in general practice has been carried out to tell the exact demographic problems with patients' access to GPs (Pickin, O'Cathain et al. 2004; Salisbury, Goodall et al. 2007), there is limited literature about detailed patient waiting issues in Australia. From empirical studies, we have found that there is a serious access problem in Australian

remote areas and rural areas where there are shortages of doctors (Si, Bailie et al. 2008). Research carried out in Wagga Wagga (Wagga Wagga is the largest inland city in the State of New South Wales with a population of about 58,000 people on an area of about 480,000 hectares.) has found that a patient might have to wait up to 55 days for a routine appointment with a GP (Knight, Padgett et al. 2005). Another study in Cootamundra revealed that patients had to book 2-3 weeks in advance and were dissatisfied (Knight, Padgett et al. 2005).

Increased non-attendance is another problem accompanied by long waiting times in the patient's admission (Murray and Berwick 2003). It general, it has been portrayed as problematic in terms of service wasted and the financial cost involved. Some non-attendance is inevitable with pre-booked appointments, as GP appointments must compete with patients' other priorities and the complexities of their day (Martin, Perfect et al. 2005). Some may be missed if, after a long time waiting for an appointment, patients find that they are better and do not need to attend or they may find a more convenient treatment from other resource (Liggett 2002). If patients gave prior notification when they are unable to attend, their appointment could be offered to other patients. Studies Indicated that the non-attendance rate increases simultaneously when the patients' waiting time to GPs consultation increases (Kennedy and Hsu 2003; Mehrotra, Keehl-Markowitz et al. 2008), although one of the studies did not find out any evidence to prove the tight link between missed appointments and waiting time (Bennett, Baxley et al. 2009). One thing is very clear that doctors' waiting lists are being unnecessarily lengthened by non-attendant patients (Liggett 2002).

There is an exception to this, however, in the Emergency Department (ED) where a patient can receive emergency treatment without GP's referral. Generally, the

purpose of ED is to provide initial treatment to patients with a broad spectrum of illnesses and injuries, some of which may be life-threatening and require immediate attention. However, ED is a place where non-urgent patients could receive timely treatment compare with the service they may receive from their own GP. Studies have revealed a universal issue that up to 60% of patients go to the ED for non-urgent problems (Nadel 1993; Afilalo, Marinovich et al. 2004; Nawar, Niska et al. 2007). Two major reasons for non-urgent patients attending ED are: (1) they were unable to obtain an appointment with a GP; and (2) it took less of their time to be seen in the emergency department than it did to contact their GP (Howard, Davis et al. 2005). However, occupying expensive ED resources may not be the cure for the illnesses of non-urgent patients. These patients will be more likely to redirect back to their GP and consume another consultation from primary care resource (Backman, Blomqvist et al. 2008).

Therefore, the significance of patient admission in primary health care has been addressed. Patient waiting is a preliminary problem and seems to be caused by the insufficient provision of service, which starts at the "gate-keeper" with the GP, but has extensive impacts on both patients' non-attendance to primary care and non-urgent patients occupying ED resources. Finally, the missed appointments and the referred back patients from the ED deteriorate the resources and patient admission in primary health care.

2. 5   A Revolutionary Model of Patient Admission in Primary Health Care

One of the main reasons to cause access difficulty is the traditional appointment model (Murray and Berwick 2003). Under the traditional appointment model, practice uses a fix schedule to take patient appointments. Once a GP's schedule on a specific day has been fixed, patient appointments are arranged in the already carved

out slots. If patient demands on that day exceed the provider's supply within the scheduled time, then the exceeded demands will be postponed into the future schedule, which cause service delay. As time goes on, the postponed appointments form a long list of backlog, which seriously impedes patients' access to health care services. Moreover, clinic receptionists have to deal with patients who have urgent requests by dividing patients into different categories and triage them with different doctors who might be available at a specific moment. This not only exacerbates the problem of patient waiting, but also hampers continuity of care (Murray and Berwick 2003).

Section 2.5 discussed service delay as one of the major reasons causing a patient to miss an appointment, which wastes the GP's precious time slot allocated to this patient. It also blocks another patient's access to the services. In the long run, the recurrence of this situation will eventually cause the deterioration of the supply of health care services (Murray and Berwick 2003; Martin, Perfect et al. 2005).

Seeing the problem with the traditional appointment model, a breakthrough one was proposed by Murray and Tantau (1998) named Advanced Access (AA) model. This model aims to balance supply and demand, diminishing the backlog of appointments and the delay of primary health care services. Since researchers have found that, in many cases, the practice backlogs remain at a stable status; this means the demand and supply are balanced. The only problem is the long time delay caused by inappropriate arrangement method (Murray and Berwick 2003). Murray was influenced by the manufactory's queuing theory, and adapted this into the AA model (Murray and Berwick 2003). According to the AA model, practices are required to provide same-day service when a patient requests an appointment. The Advanced Access model proposes to achieve this goal through the implementation of six

strategies: "balancing supply and demand, reducing backlog, reducing the variety of appointment types, developing contingency plans for unusual circumstances, working to adjust demand profiles, and increasing the availability of bottleneck resources" (Murray and Berwick 2003). Direct benefits of Advanced Access include significant improvement in patient accessibility (Knight, Padgett et al. 2005; Salisbury, Goodall et al. 2007; Salisbury, Montgomery et al. 2007; Tantau and Tantau 2009); the reduction of patients' no-show rates (Knight, Padgett et al. 2005; Tantau and Tantau 2009); and improvements in the performance of treatment (Subramanian, Ackermann et al. 2009).

There are 6 specific changes suggested by Murray and Berwick (2003) needed to implement the AA in the practice:

- Balance Supply and Demand

- Work Down the Backlog

- Reduce the Number of Appointment Types

- Develop Contingency Plans

- Reduce and Shape the Demand for Visits

- Increase the Effective supply Especially of Bottleneck Resources

Different to these guidelines, Advanced Access promoted in the UK focused on five principles to achieve their access target (Oldham 2001): understanding the demand profile over time; managing demand by offering alternative forms of provision; ensuring that the capacity meets demand; making contingency plans for times when there are fluctuations in demand; and involving patients in planning changes. The shared characteristics of these two approaches are (1) setting up an access target (same-day access for original model and 48 hours for UK); (2) monitoring the

patient's demand; and (3) intervening in the provider's supply to meet patient's demand.

To date, the AA model is the best primary health care management model in terms of providing timely services to patients (Murray and Berwick 2003). It is promoted in England by the National Primary Care Development Team as a way of improving access and achieving National Health Service (NHS) planned access targets in 2000 (Department of Health 2000). Studies indicate that 67% of practices in England claimed to operate Advanced Access by the year of 2007 (Salisbury, Montgomery et al. 2007). In Australia, Australian Primary Care Collaborative (APCC) has set down its Phase 2 program in December 2007, and one of the topics is to improving patient access to primary care (Knight 2009).

The implementation of AA in the practice has faced many challenges not as easy as the explanation of the name. As indicated above, the initiative of Advanced Access was well accepted in USA, UK and other countries. However, implementing the AA model poses many new challenges to primary health care services. It requires shifting the criteria for appointment decision making from provider's schedule to patient's demand (Ahluwalia, Offredy et al. 2005; Hroscikoski, Solberg et al. 2006). The huge effort to manage the demand and supply leads to complex changes not only reflecting on the accessibility and no-show rates, but also continuity of care, providers' workload and practice working culture (Dixon, Sampson et al. 2006). For example, it requires receptionist and practice manager to take extra work to record patient's request on paper, and evaluate the daily change of every service provider's work load, accessibility and continuity of care (Baxley, Weir et al. 2009).

2. 6   Important Issues for Designing an Appointment System

In order to design an effective Appointment System to support patient admission in primary health care, especially for improving service performance and provider's collaboration, it is essential to understand the important issues relating to design. In this section, a list of the critical issues in designing the appointment system, extracted from reported research evidences, is summarised below. These issues include: managing patient demand and health supply; supporting collaboration; evaluating service performance and providing alternative patient entry. The following subsections will examine these barriers in detail.

2.6.1   Revealing Patients Demand

It is recommended by Murray (2003) that knowing the appointment demand is the precondition for planning health care supply, even though measuring appointments demanded but not available proved to be a credible customer-focused approach to benchmarking against set goals (Ledlow, Bradshaw et al. 2000). However, because of a lack of clinical guidelines for the implementation of the Advanced Access model, some practices did not mention that they had recorded patient's demand (Murray, Bodenheimer et al. 2003; Mehrotra, Keehl-Markowitz et al. 2008; Phan and Brown 2009), or measured patients' demand merely by the receptionists' manually noting and counting the number of calls each day (Murray, Bodenheimer et al. 2003; Baxley, Weir et al. 2009); If the practice did not record patient demand, doctors would not really be aware of the average daily demand, so that a fluctuation of patients' demand would make them nervous. However, the patients' real demand is not equal to the number of requests from phone calls, because certain number of patients would not be offered an appointment, and they were more likely to make call back

some days later. The problem is that no matter how many calls this patient made, his demand for health care service is only met once.

2.6.2 Measuring Service Performance

The major concerns in implementing the advanced access model in the practices have been focused on service accessibility, continuity of care and providers' workload. These three characteristics may also be applicable in the design of appointment system to improving patients' access to primary health care.

2.6.2.1 Accessibility

Previously, an appointment system was used to record patients into the providers' schedule. Thus patient access to primary care appointments was not routinely measured until the increasing interest in this aspect of practice activity (Jones, Elwyn et al. 2003). However, the lack of a widely agreed measurement method to represent patient access to primary care service will make it harder for practice to compare their response to patient demand with a standard measurement (Jones, Elwyn et al. 2003). In order to build an appointment system, which supports the practice continuously working down the backlog and develop contingency plans for the change of accessibility, it is necessary of have a method for measuring access that is valid, reliable and quick, and provides a daily longitudinal record of access both on organisational basis and for individual practitioners when implementing a service model to improve patient accessibility in primary health care.

One of the assessment methods is called Access Response index (AROS) (Elwyn, Jones et al. 2003) and has been used in ten practices. The major process for this method is to record the number of days until the next available routine appointment with any doctor (excluding weekend days and bank holidays) at 4pm for full-time

practitioner and 12pm for part-time practitioner. This is a very straight forward method to assess accessibility, of which the principle is simplicity and ease of regular data collection, with data patterns capable of indicating trends in organisations can be generated rather than data on individual clinician availability.

However, a noticeable barrier of this method is that the "next available appointment" is sensitive to patient's withdrawing a request for of service. For example, an appointment may be open at the time of a request because of a cancellation or other unexpected event. Another problem is this method only tracks the overall waiting time but not every individual practitioner. The Advanced Access model also requires the continuous monitoring of every practitioner's availability.

Another popular access method is called the 'third next available' appointment, which is mostly used in Primary Care Collaborative in England rather than the "next available" appointment (IHI.org). Using the 'third next available' appointment eliminates these chance occurrences from the measure of availability (IHI.org).

The instruction to calculate the 'third next available' appointment is as follows (IHI.org):

- Sample all physicians on team the same day of the week, once a week.

- Count the number of days between a request for an appointment with a physician and the third next available appointment for a new patient physical, routine exam, or return visit exam.

- Report the average number of days for all physicians sampled. Note: count calendar days (e.g. include weekends) and days off. Do not count any saved appointments for urgent visits (since they are "blocked off" on the schedule.) The data collection can be done manually or electronically.

- Manual collection means looking in the schedule book and counting from the "index" (day when the "dummy" appointment is requested) to the day of the third available appointment.

2.6.2.2 Continuity

Access is an important determinant of health care quality; there are some other important determinants of the overall quality of appointment service, such as continuity of care (Jones, Elwyn et al. 2003). Alazri and Heywood (2007) state that the definitions of continuity described by researchers are various, include:

- Longitudinal continuity: ongoing care from the same health care professional or as few professionals as possible, consistent with other needs;

- Relational continuity: care from one or more named individual professionals with whom the patient can establish and maintain a therapeutic relationship;

- Team continuity: care provided by a group of health care professionals working together in the same practice providing consistent communication and coordination of care for their patients;

- Continuity of information: Care provided by different health care professionals either in primary or secondary care, with continuity archived by the availability of records;

- Experienced continuity: the coordinated progression of care from the patient perspective;

- Cross-boundary continuity: services that follow the patient when moving from one setting to another;

- Management continuity: consistent and coherent approach to the management of a health condition that is responsive to a patient's changing needs.

Different research definitions of continuity may have different scope. One study carried out by Phan and Brown (2009) pointed out that by providing Advanced

Access scheduling, the continuity of care between patients and physicians decreased from what it was in a system based on scheduled appointments. The continuity in this case referred to the longitudinal continuity. However, as the person to put patients in providers' schedule, the receptionist preferred to use the term of team continuity, followed by cross-boundary continuity, continuity of information, experienced continuity, and finally longitudinal continuity (Alazri, Heywood et al. 2007). Thus, choosing a proper measurement of continuity is as important as measuring accessibility. Unfortunately, there is no regulation now to justify the importance and appliance of different terms of continuity.

2.6.2.3 Workload

Beyond the immediate impact on GP waiting time, providers has been strongly concerned about whether improving patients' access would affect workload (Dixon, Sampson et al. 2006). For the provider this concern is partly caused by the uncertainty of the appointment demand on average and its fluctuation, and partly caused by the undefined flexibility of their workload to accommodate the temporal fluctuations in demand. Thus some staff continued to view demand as infinite (Pope, Banks et al. 2008). For receptionist, almost all the field studies described that their workload were increased either to maintain manual records, data requirements and daily reporting criteria, or supervise cross-checked daily data to ensure accuracy throughout the implementation; however, studies also indicated that they could be relieved from exhausting triage work (Meade and Brown 2006).

2.6.3 Balance Demand and Supply

To balance patients' appointment demand and health care supply is the fundamental belief in reducing patients' waiting time for both Murray's six steps to achieve

Advanced Access and Oldham's five principles. However, this target is achieved by a simple instant action without consideration when a patient calls in and his/her request is offered an appointment or postponed in the future. Incentives to use Advanced Access were encouraged by targets requiring practices to offer an appointment with a doctor within 48 hours in England. Many practices conflated there initiatives and simply viewed same-day appointment systems as a way to meet access targets (Pope, Banks et al. 2008). However, balancing demand and supply is not only a matter of squeezing patients into providers' schedules, but also balancing all the aspects of quality harmoniously. These aspects include patients' need for access (immediate access and pre-scheduled appointment), continuity (which various for different patients' groups (Mainous, Salisbury et al. 2009)), as well as the providers' workloads. Even though the informal strategies ('rules of thumb' cite by the author) used by receptionists to triage patients' requests is still working well (Pope, Banks et al. 2008), it may not be suitable for sustaining timely access to the practice, since many studies indicate that accessibility dropped during a long period after an immediate impact (Mehrotra, Keehl-Markowitz et al. 2008).

2. 7   Summary

In conclusion, this chapter first introduced the health care system in Australia, discussing this from two perspectives: providers and insurance. It also discussed the need for collaboration among different specialties for the purpose of chronic disease management. These issues shaped the practice workflow in Australian primary health care. After this, a study of problems with patient admissions in primary health care was presented. These problems included the patient's long waiting time for an appointment; the patient's 'no-shown' in the practice; and wasting precious health care resource. In order to indentify the causes of these problems and their possible

solutions, this chapter reviewed two appointment models: the traditional appointment model, and the Advanced Access model. In the conclusion, important issues that need to be considered in designing an appointment system to improve the patient's access were presented.

3. METHODOLOGY

3. 1 Introduction

This chapter describes the research methods used and approach taken for the appointment system design. The organisation of the chapter is as follows: Section 3.2 briefly reviews the research objectives and questions. Section 3.3 outlines the three research phases, which followed the basic principles of the waterfall model of Software Development Life Cycle (SDLC). Research methods, which were employed in each research step, were listed in the corresponding sections. Section 3.4 describes research activities and methods for research Phase 1: requirement analysis. Section 3.5 details the methods and tools for system design in research Phase 2, and Section 3.6 present methods used in prototyping and unit testing in research Phase 3, including a description of tools used in this process. The chapter concludes by outlining the timeframe for the study.

3. 2 A Brief Review of Research Objective and Questions

The aim of this research is to design a computer based appointment system to improve patients' access to primary health care. This requires firstly identifying the key characteristics of patient booking in primary health in the Centre Health Complex (CHC), and then developing efficient functions to speed up the patients' admission process. To achieve the aim of the research, the following three major research questions are posed (as proposed in Section 1.3):

Question 1: What do GPs, AHPs and patients do during the patient booking process?

1.1. What is the traditional appointment model?

1.2. Who are the actors and what do they do in the appointment booking process in CHC?

Question 2: What are the weaknesses of the traditional patient booking system?

    2.1. What are the problems with the traditional workflow of patient booking process?

    2.2. What are the problems with the existing appointment system?

Question 3: How can a new computer-based booking system be designed to fill the gaps of the traditional patient booking system?

    3.1. What is the new appointment model that can be implemented to improve patients' access?

    3.2. How to design a new appointment system which can support the implementation of the new appointment model?

    3.3. How to ensure that the new appointment system would be supported by the existing CIS infrastructure used in CHC?

3. 3   Software Development Methodology Adopted in this Study

"A system has a life of its own. It starts as an idea and progresses until this idea germinates and dies when it is discarded" Keyes said (2003). There are several well-known models of Systems Development Life Cycle Models including "waterfall," "fountain," "spiral," "build and fix," "rapid prototyping," "incremental," and "synchronize and stabilize". The original and still frequently used systems development model (method), that was originally regarded as "the Systems Development Life Cycle" is the waterfall model: a sequence of stages in which the output of each stage becomes the input for the next (Keyes 2003). Waterfall model is a classical linear and sequential approach to software design and systems development, which is originally composed of seven ordered sequences (Royce 1970) (in Figure 3-1): (1) requirement specification, (2) design, (3) construction, (4) integration, (5) testing and debugging, (6) installation, and (7) operation. The first, formal, description of this model, was proposed by Dr. Royce in 1970. Many

descendant software development models have born some similarity to the waterfall model, as all software development models will incorporate at least some phases similar to those used within the waterfall model.

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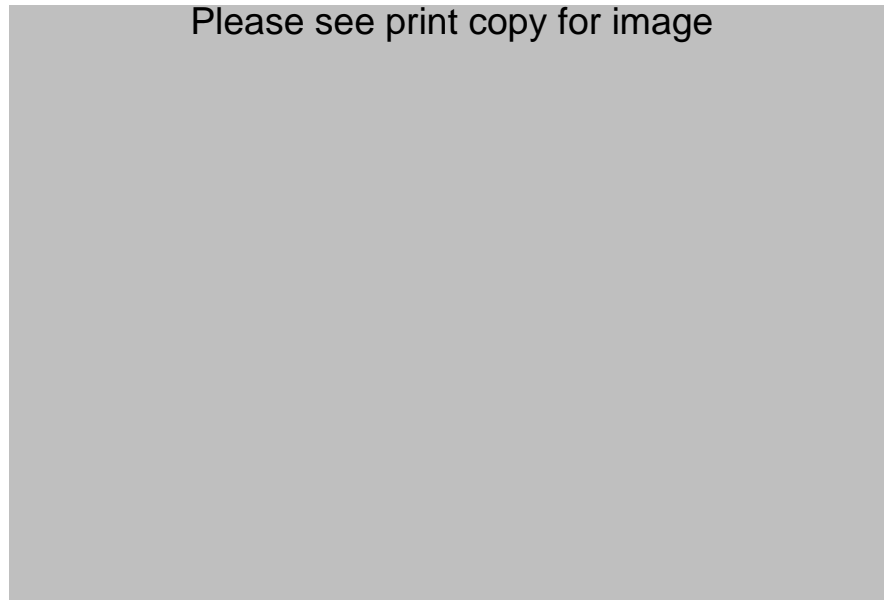
Figure 3-1 Original waterfall model for Software Development proposed by Dr.

Royce in 1970

In order to solve the three research questions proposed in this study, we have employed a customised waterfall model, which was incorporated by a descendant waterfall model proposed by Leffingwell (2003). Leffingwell's waterfall model is composed of five inter-dependent steps: (1) requirement, (2) design, (3) coding and unit test, (4) system integration, and (5) operation and maintenance. Leffingwell's model was slightly modified in step (3), (4) and (5). Coding was converted to prototyping to fit with the research nature of this project. System integration was renamed: "implementation". Constrained by the time limit, this project did not plan the operation and maintenance stage and the implemented stage has not been fully conducted.

As a result, this customised model is composed of four phases (See Figure 3-2): (1) requirement analysis, (2) System Design, (3) prototyping and unit testing, and (4) implementation.
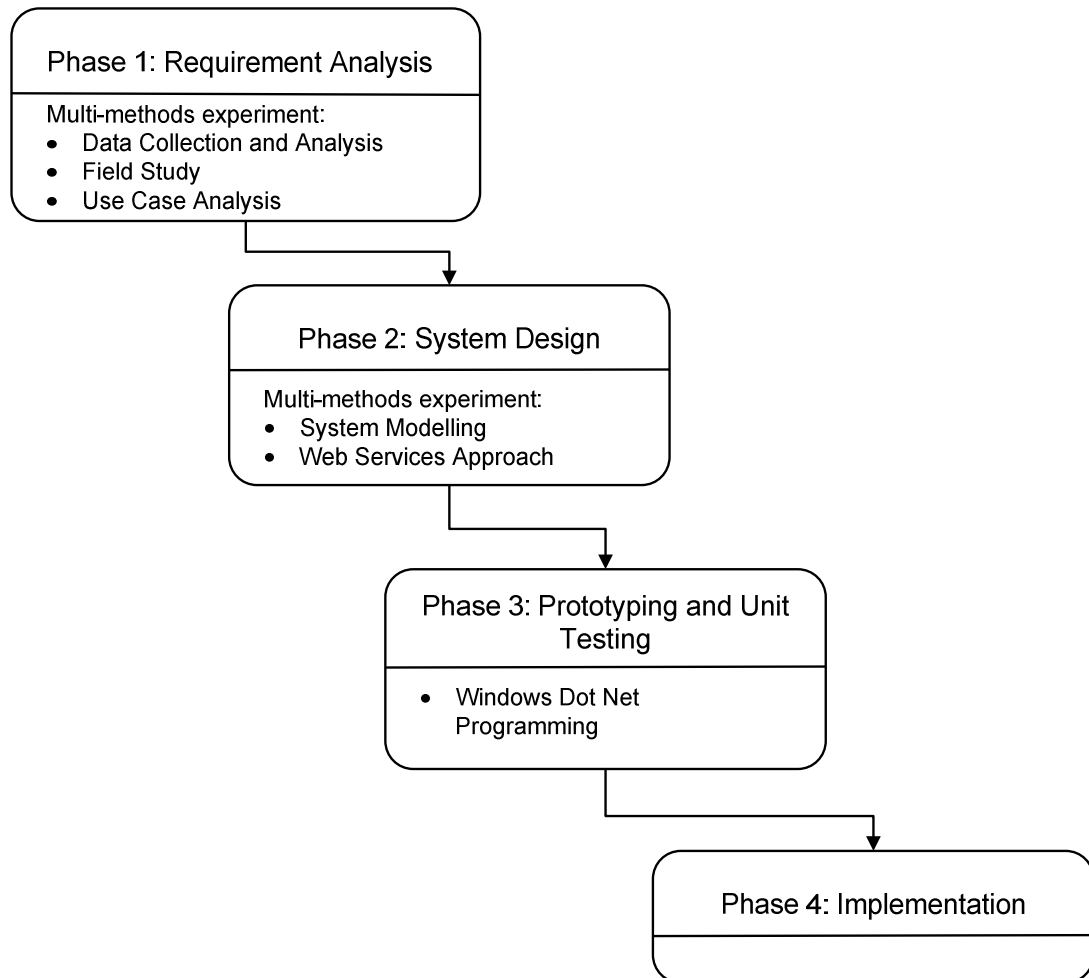
Figure 3-2: Research Phases and Methods used in each phase

We adapted three research methods in research Phase1: data collection and analysis, field study and use case analysis. All of these three methods guided the development of detailed requirements for constructing the integrated appointment system to improve patient access to primary health care in CHC. Data collection and analysis involved reviewing of existing publications on the related field and helps to identify the common problems and related solutions. Field study has been conducted to extract specific problem from the clinic where this research has been taken, and use

cases are used to documenting the clinical process. By analysing use cases can help to see whether the existing solutions are in accordance with these specific problems.

Research Phase2 is system design. There are two methods adapted in this research phase: system modelling and web service approach. Modelling is a major approach to describe the design of the integrated appointment system. Web service is a new system built approach. In this, the appointment system could be compatible with any operating system.

Research Phase 3 is prototyping and unit testing. Prototype software based on the design in Research Phase2 is presented. . Net technology is adapted as the Programming method. This technology is based on Microsoft .NET Framework and the applications are run on Windows Operating System (OS). Unit testing as a code testing method is also based on this technology.

The objective of Research Phase 4 is to implement the prototype of the appointment system in CHC. Due to the time limits, the prototype has not been fully implemented in CHC. The details in this phase have been excluded from the thesis.

The following sections will present in detail, methods which have been applied in each of the three implemented three research phases.

3. 4   Methods Employed in Phase 1: Requirement Analysis

Requirements analysis in this research encompassed those tasks that go into determining the functional and non-functional features required for the appointment system in a clinical environment. The general workflow in this phase was presented in Figure 3-3. The features were identified based on analysing data gathered from the literature and the research field. The user case analysis was used to apply the problems, which were found in existing literature, to the specific situation in CHC, so that the weak point of the existing workflow can be accurately identified through

the analysis process. This analysis result was organised as an artefact produced by the end of this phase.
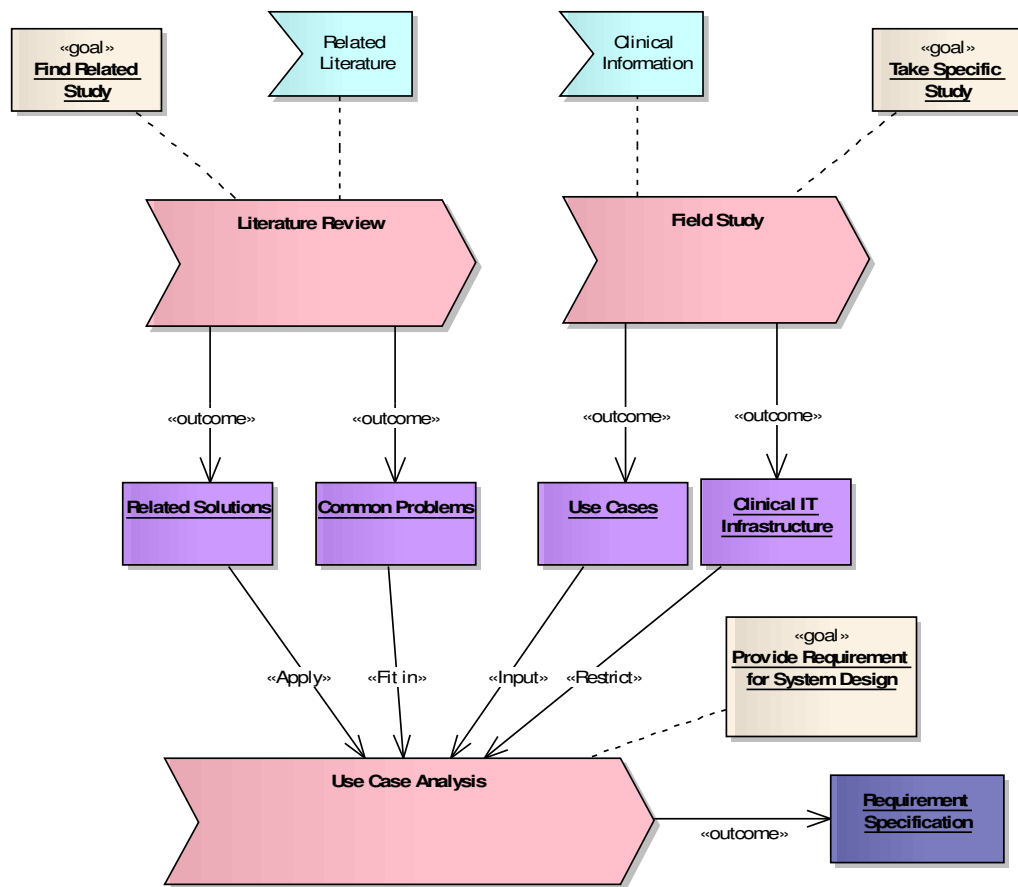
Figure 3-3: Input and Output in each step of this research phase

3.4.1 Data Collection and Analysis

Reviewing the literature is a crucial step for conducting researches and the foundation for developing research papers, policy and regulatory statements, evidence based health care statements for professionals, and consumer materials (Garrard 2006). The literature review was the main approach for data collection. The purpose of the literature review was to deepen the researcher's knowledge on the research topic. This includes building solid understanding about the research background; expanding the view of common problems which were addressed in the

literature and compound environment to cause these problems; and organising possible solutions which were proposed in some studies.

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┌──────────┐   ┌──────────┐   ┌──────────┐   ┌──────────┐   ┌──────────┐   ┌──────────┐
│ Defining │   │Identifying│  │          │   │Literature│   │ Further  │   │  Result  │
│  Search  │──▶│ Suitable │──▶│  Search  │──▶│Selection │──▶│Retrieval │──▶│ Sorting  │
│  Terms   │   │ Sources  │   │          │   │          │   │          │   │          │
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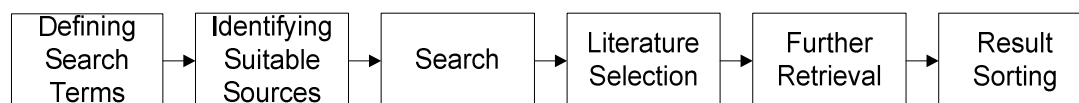
Figure 3-4: Procedure to Collect Data from Literature

Mary Hickson (2008) has provided well organised principles for reviewing the literature for health care professionals. These principles include (1) defining search terms from the research question; (2) identifying suitable sources of evidence; (3) devising a research strategy to get results effectively; and finally (4) composing a literature review. In this research, the data collection procedure is described in Figure 3-4.

First, we identified the preliminary searches terms which were allocated on the following topics:

- Collaborative primary health care in Australia

- Patient access to primary health care (including Australia)

- System integration of clinical information system

Medline, PubMed and Meditext were searched for relevant publications between 1991 and 2009. The following MeSH terms were used: family practice, health service accessibility, appointments and schedules, system integration and software design. In addition the following key words were used: Enhanced Primary Care (EPC), collaborative health care, and Advanced Access (Open Access, Same-day Access). Terms were used both singly and in combination. Citations and abstracts were appraised for relevance and full articles selected for filtering. Apart from the selected literature, related studies were also retrieved from citations occurring in this

research literature. The information gathered from literature was then sorted into two categories: (1) to provide knowledge for understanding the research background, and (2) to provide ideas for system design. The artefacts in this study has been organised in Chapter 2 Literature Review. Research Quest 1.1 and 1.3 was answered by this study.

3.4.2   Field Study in the Centre Health Complex

The literature review and analysis indicated that there did not appear to be any existing computer based appointment system for improving patient access to Australian primary health care. Moreover, most practice solutions, which we found in the literature, might be only suitable for a specific practice environment, due to the complexity of working culture in health care (Gill and Gill 2004). Thus, the field study which we conducted in the Centre Health Complex brought us a very concrete view of the problem as it happened in the real practice field.

The "blastoff meeting", which is considered as the first step in requirement gathering process (Robertson and Robertson 2002), discussed the collaboration between project team members and this was settled at the beginning of this project. Two tasks were assigned in the field study. One task was to address the working flow of health care providers and the patient journey in CHC during the appointment process undertaken by the interviewing receptionist, GP, practice manager and/or administrative staff. The other one was to examine the exiting CIS used in CHC, and finally, the composing of an IT infrastructure report, which would regulate the design of appointment system framework. The IT infrastructure report was composed from the following perspectives: (1) Network, (2) Hardware, and (3) Software.

The artefacts in this study were expressed in the form of Unified Modelling Language (UML) diagrams including use case diagrams and activity diagrams; and

Entity-Relationship (E-R) diagram. Firstly, use case diagrams were used to present the functions provided by the existing appointment system. These use cases give an overview of the appointment system. The detailed workflow of each use cases will be described throw activity diagrams. Apart from that, E-R diagram will be used to describe the static data stored in the CIS database. In this study, Research Question 1.2 has been answered and the details of this study were recorded in Chapter 4 Result of Field.

3.4.3   Use Case Analysis

The Use Case analysis was the procedure used to create requirements specification in this research. The weak points of the existing appointment system were analysed, in particular, those which hamper the patient's admission in the medical centre. We listed the important factors in designing an appointment system and the inability with the traditional appointment model in Chapter 2. Since the objective of this research is to break down these barriers created by the existing appointment system and workflow, the important factors for improving patients' access were mapped in the specific design of the existing system. And the design of a new appointment system was to fulfil these identified specific requirements. In this study, Research Question 2.2 was answered, and the details of this study were recorded in Chapter 5.

3. 5   Methods Employed in Phase 2: System Design

System Design is the core step in this research. The design of the new appointment system answered the two questions, which have been cited in section 3.2. UML based System modelling was used as a major method to present the design of the new system, which was devised to overcome barriers identified in Research Phase 1. The design of the appointment system framework was followed with the principles of for

constructing web services, so that the new appointment system could integrate with existing legacy software in CHC. In this study, the Research Question 3.2 and 3.3 were answered and the artefacts of this study were documented in Chapter 7.

3.5.1 System Modelling

System development is a problem-solving process that involves understanding the problem, solving the problem, and implementing the solution (Alhir 2003). Modelling could make this process much easier by providing three key benefits: visualisation, complexity management and clear communication. The Unified Modelling Language (UML) is a such language for writing software blueprints (Booch, Rumbaugh et al. 2005).

The brief introduction of UML and UML diagrams in this section is intended to provide the reader with general background material for understanding the system design in Chapter 5. In this study, UML diagrams, by which we could view the system building blocks, were used during processes of use case analysis and system modelling. As suggested by the UML modelling, complex systems can be understood from different perspectives (Booch, Rumbaugh et al. 2005), we have adapted number of diagrams on different aspects for describing the existing appointment system and the design of the new appointment system, independently. These diagrams include:

- **Use Case diagram**: A use case diagram shows a set of use cases and actors and their relationships.

- **Sequence diagram**: A sequence diagram is an interaction diagram that emphasizes the time ordering of messages.

- **Activity diagram**: An activity diagram shows the flow from activity to activity within a system.

- **Class diagram**: A class diagram shows a set of classes, interfaces, and collaborations and their relationships.

3.5.2 Web Services

By definition, "a service-oriented architecture (SOA) is a style of design that guides all aspects of creating and using business services throughout their lifecycle (from conception to retirement), as well as defining and provisioning the IT infrastructure that allows different applications to exchange data and participate in business processes regardless of the operating systems or programming languages underlying those applications" (Newcomer and Lomow 2005). Web services have taken this concept and implemented it as services delivered over the web using technologies such as Extensible Mark-up Language (XML), Web Services Description Language (WSDL), Simple Object Access Protocol (SOAP), and Universal Description, Discovery, and Integration (UDDI) (W3C 2004). They are self-contained, self-described, modular applications that can be published, located, and invoked across the Web (Lau and Mylopoulos 2004). Web services provide a standard means of interoperating between different software applications, running on a variety of platforms and/or frameworks. Web services are characterized by their great interoperability and extensibility, as well as their machine-processable descriptions (W3C 2009).

The reason for us to select web services as an implementation solution is taking its advantage of integrating complex hardware and software environment together, and the need for scalability to accommodate the potential future integration of services over regional health care providers (or the in-depth integration of functions provided by the isolated EMR system) in CHC. Ideally, the system could be adopted to integrate the booking services in a large area to enable the patients and other

providers to view the availability of providers from different organisations in this area. The motivation for the selection of Web services is to enable the integration of cross-organisational information services, similar as those Web-service based solutions that have been implemented in hotel and air ticket services (W3C 2002). Web services were adapted as a standardised way of integrating Web-based applications using the XML, SOAP, WSDL, and UDDI open standards over an Internet protocol backbone. XML is the basic foundation of which web services and is used to tag the data, SOAP is used to transfer the data, WSDL is used for describing the services available, and UDDI is used for listing what services are available. Once the WSDL is obtained from the UDDI or other location, a SOAP message is generated for transmission to the remote site (Newcomer 2002).

3. 6   Methods Employed in Phase 3: Prototyping and Unit Testing

In general, the conventional purpose of a prototype is to allow users of the software to evaluate developers' proposals for the design of the eventual product by actually trying them out, rather than having to interpret and evaluate the design based on descriptions. This stage is crucial, especially for this design, because the proposed appointment system in the real clinical environment could be a dedicated component of a CIS. This means a set of software interfaces of the new system is needed in order to adjust to various other components of CIS on the market. With prototyping, we could easily justify the design regardless the diversity situation, which could be faced by the eventual product.

The system design has followed basic principles of SOA, and functionalities were constructed in the form of web services for the purpose of system reusability and platform independent. This made the new design considerably easy to build, however, also made it more challenging to test. Individual web services usually provide just an

interface, enough to invoke them and develop some general (black-box) tests; however insufficient for a tester to develop an adequate understanding of the integration quality between the application and independent web services (Bartolini, Bertolino et al. 2009). Thus, we utilised unit testing technique, which is a piece of code written by a developer that exercises a very small specific area of functionality of the code being tested, and are performed to prove that a piece of code dose what the developer thinks it should do (Hunt 2004). In this way, we tested important functions inside the every web service we have designed.

3.6.1 Microsoft.NET Framework

The prototype appointment system was built on top of the Microsoft Windows operating system based .NET Framework, which is an integral Windows component that supports building and running the next generation of applications and XML Web services (MSDN 2009). There were several reasons to make this decision. Firstly, almost all of the clinical office operating systems were Microsoft Window OS when we were doing this project. Second, the practice software, which was used by GPs, was windows based software, and most clinic data was managed by Microsoft SQL Server 2005. Last but not the least, we repaired a vacant windows server and this server is used to run the prototype application.

3.6.2   Tools Used in this project

Various technologies were employed in designing and prototyping this appointment system in this project, which included: UML modelling, Windows programming, Database design and web services design. So we utilised a suite of computer applications to support our study. The application tools used are displayed in Table 3-1:

Table 3-1: The application tools used for the development of the appointment system and their tasks they undertake.

Tool	Tasks
Microsoft Visual Studio 2008	Prototyping and Web Services Design
Microsoft Expression Studio	Web Page Editor
Microsoft SQL Server 2005	Database Design
Microsoft Visio 2005	Flow Diagram Design
Enterprise Architect 7.0	UML Modelling

3. 7 Time Line for this Study

This Masters research took the candidate one and a half years. The summary of the timeframe spent on each research activity in the whole study is shown in Table 3-2

Table 3-2 Time Line for each activity undertaken in this research project

Research Phase	Research Activity	Timeframe
Phase 1: Requirement Analysis	Data Collection & Analysis	September -- November 2008
	Field Study in Centre Health Complex	December 2008 – March 2009
	Use Case Analysis	April 2008
Phase 2: System Design	System Modelling	May 2009
	Framework Design	June 2009
Phase 3: Prototyping and Unit Testing	Prototyping	July – August 2009
	Testing	September 2009
Thesis writing	Result reporting and Thesis Writing	October 2009 – March 2010

3. 8 Summary

This chapter has presented the research design and approach, followed by the sequence of research methods undertaken for this research. Three phases of design, which were enlightened by SDLC, were undertaken. Various sources of data were accessed to gather applicable information for this project, i.e. literature review and the filed study. The process of designing the appointment system is guided by the

requirements specification produced in the requirement analysis process. Then a prototype system was constructed and implemented in the clinic's working environment. Moreover, a system testing approach was also employed to justify the correctness of the design. Finally, the timeframe for each research activity was presented.

4. RESULT OF FIELD STUDY

4. 1   Introduction

This chapter presents in detail the results of the field study in Research Phase1: Requirement Analysis. These results were gathered from Centre Health Complex (CHC). Section 4.2 briefly introduces patients' admissions in CHC. Section 4.3 presents the study result of providers' working flow for booking patients. Section 4.4 presents the existing data structure for recording booking information and section 4.5 presents the patient journey to attend different services in the medical centre. This is followed by the study of the existing IT infrastructure in CHC in section 4.6. Because the booking process in allied healthcare is similar to the GP's section, the booking process in allied healthcare is not repeated in this chapter. In Section 4.7, this chapter concludes with a summary.

4. 2   A Brief Introduction to the Patient Admission Process in CHC

Centre Health Complex is a multi-disciplinary medical centre, which is located in the central area of Shellharbour in New South Wales. The clinic offers primary healthcare services to both pre-scheduled booking patients and walk-in patients. Generally, patients are recommended by the practice to make appointment with a GP during business hours from 8:30 am to 5 pm, and they are also free to come any time after 5 pm without making appointment. Everyday there were approximately 240 patients being seen by GPs in the family healthcare section.

During the period of field study, we found that there were constant delays for patients to access to GPs' service. We analysed three GPs' appointment data from the existing EMR system and calculated the trends of services delay from 1st January 2007 to 1st January 2010. The service delay was represented by the number of days

between the day of the appointment and the day the appointment was fulfilled. As was found in the practice, this delay was mainly caused by the providers' backlogs: that is, a provider's schedule was fully booked out three days in advance, so that the closest available appointment would be on the fourth day. The limitation of this definition is that some patients would like to plan their appointments several days in advance. In this case, service delay is the wrong interpretation of the duration between the time of request and the time of appointment.
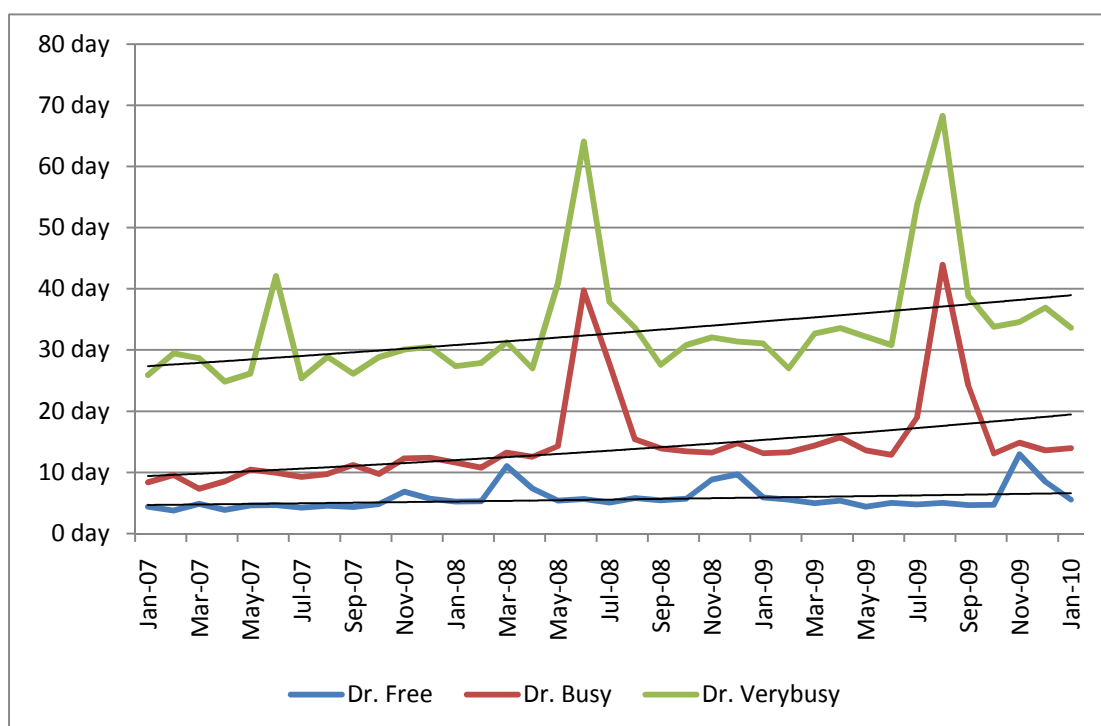
Figure 4-1: The changes of the average appointment delay between Jan 2007 and Jan 2010 for a patient who saw either Dr. Free, Dr. Busy or Dr. Verybusy.

In Figure 4-1, the horizontal axis represents the month from Jan 2007 to Jan 2010, and the vertical axis represents the number of waiting days. The three lines describe the number of days that a patient needed to wait before seeing a particular GP, named Dr. Free, Dr. Busy and Dr. Verybusy, respectively. The average duration of waiting time for these three GPs were 4.7days, 9.9 days and 28.9 days in 2007. These numbers had reached to 5.9 days, 17.6 days and 37.8 days in 2009 respectively. The

waiting time has an obvious increasing trend. The peak waititng time for Dr. Verybusy happened in June 2007, June 2008 and Auguest 2009; for Dr. Busy this happened in June 2008 and Auguest 2009; and for Dr. Free it happened in March 2008, December 2008 and December 2009. All these increment were caused by the short absense of the relevant GP from practice due to holiday leave.
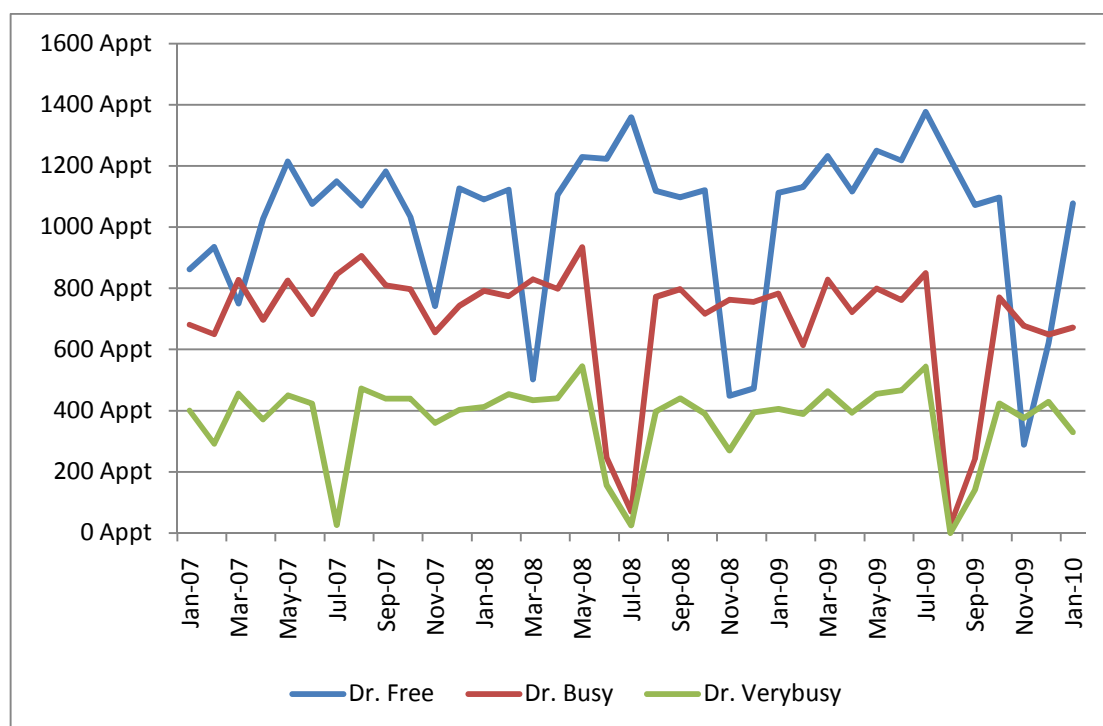
Figure 4-2: The changes of provided appointments to patients between Jan 2007 to Jan 2010 for Dr. Free, Dr. Busy and Dr. Verybusy.

In Figure 4-2, the horizontal axis represents the month from Jan 07 to Jan 10, and the vertical axis represents the number of appointments provided in a month. In constrast to the increasing delay, the overall services provided by each of these three GPs had no obvious increasing or decreasing trends. The steep drop of the service provision was casued by the absense of the provider (on holiday leave).

Because of the limitations of data, the change of patients' no-show rates was not able to be caculated. However, these two diagrams give us clear indication that (1) these three doctors did not have a target of maxium size of pre-scheduled appointments, so

that the patient's mean waiting time for these three GPs had notable difference; and (2) the practice did not take action to guarantee patient access, thus the waiting hours fluctuated dramatically and had an obvious increase over the three year period.

Because the allied healthcare professionals used an even weaker system to manage patient appointments, the data about the time required to fulfil an appointment can not be collected; however, the information collected from interviewing the receptionist, the physiotherapist and the podiatrist points to a even worse situation for patients wanting to access allied health care services. Patients may need to wait as long as four weeks for to see the physiotherapist and twelve weeks to see the podiatrist. To make a prescheduled appointment with a GP in CHC, the waiting time for a patient is about 9 days on average. To make a prescheduled appointment with a GP in CHC, the waiting time for a patient is about 9 days on average. One of the factors, which differentiates the waiting time between GPs and AHPs, has been that the consultation time with an AHP is much longer than with a GP. In CHC it usually takes about 30 minutes for a standard AHP appointment. In constrast it usually takes appromixly 12 minutes for a GP. This means that seeing the same ammount of patients it takes twice as much time for an AHP than for a GP.

4. 3   Workflow for Patient Booking

The study of workflow for patients booking was to determine how receptionist, practice manager, GP and computer system can work together to make an appointment for a patient. This process starts with a patient making a reservation from a phone call, and concludes with the appointment seeing a doctor. The findings are presented in the following sections.

4.3.1   The Actors Involved in Patient Booking Process

The study of the actors involved in Centre Health Complex aimed at clarifying the roles played by each person and identifying the links among healthcare providers who collaborate to fulfil a patient's request for an appointment. The result of this study was concluded with interviews with the practice manager, the business manager and a receptionist in the CHC.
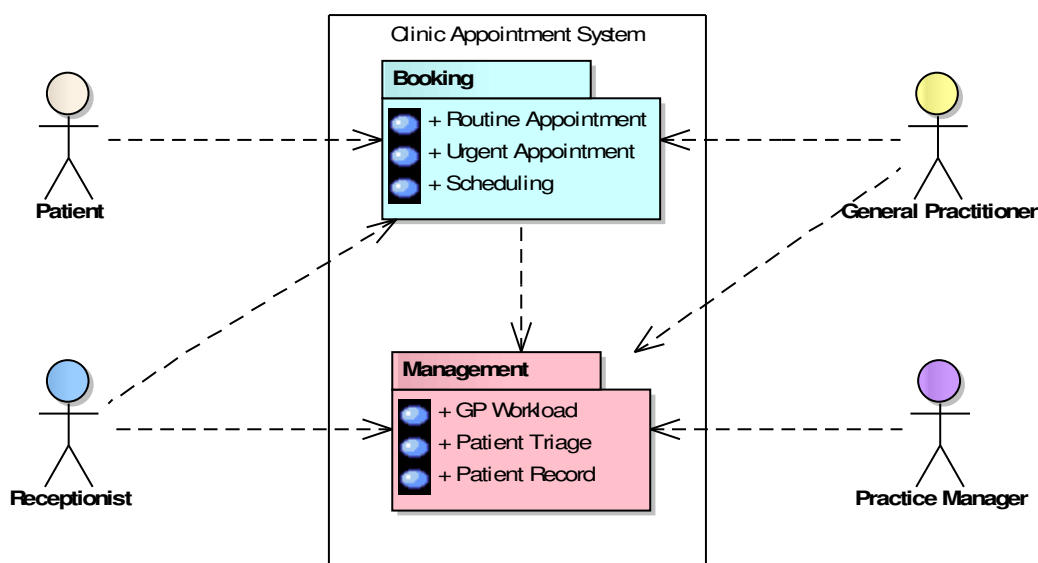
Figure 4-3 Use Case Diagram: actors and activities involved in patient booking

process in CHC

As show in Figure 4-3, there were four major actors participating in the patient booking process: patient, receptionist, general practitioner and practice manager. These actors were involved in two groups of activities, booking activities and management activities. The detailed roles played by each actor are listed and explained in table 4-1(see next page):

Table 4-1 the activities played by the four actors in patient booking process.

Actor	Activity	Description
Patient	Routine appointment	A patient can make a routine appointment with receptionist.
	Urgent appointment	A patient can make an urgent appointment with receptionist if this patient has urgent need.
Receptionist	Routine appointment	A receptionist is responsible for answering patient request.
	Urgent appointment	A receptionist is responsible for answering patient's urgent request.
	Scheduling	A receptionist makes a patient's appointment according to a GP's schedule.
	Patient triage	A receptionist will decide whether a patient who claims to have urgent issue should be given priority to see a GP.
	Patient record	A receptionist is in charge of recording patient information in the EMR and checking the correctness of existing patient records.
Practice Manager	Patient triage	Practice manager will support receptionist to triage patient with urgent condition.
	GP workload	When there are more patient requests to see a doctor than a GP's schedule allows, the practice manager would discuss with the GP whether more appointment could be provided
General Practitioner	Scheduling	Patient appointments are arranged in slots of GP schedule
	GP workload	GP discusses with practice manager about increasing workload if he/she could not provide sufficient service within his/her default workload.

4.3.2 The workflow of a patient booking

The purpose of studying the workflow of a patient's booking is to understand how the internal actors could cooperate to optimise appointments for patients. This study is drawn from the interview with the practice manager, the business manager and a receptionist. The researcher then represents the content of the interview records, and the appointment booking process into a UML activity diagram (see Figure 4-4 next page). All of the activities are stamped with a number, for the convenience of description.
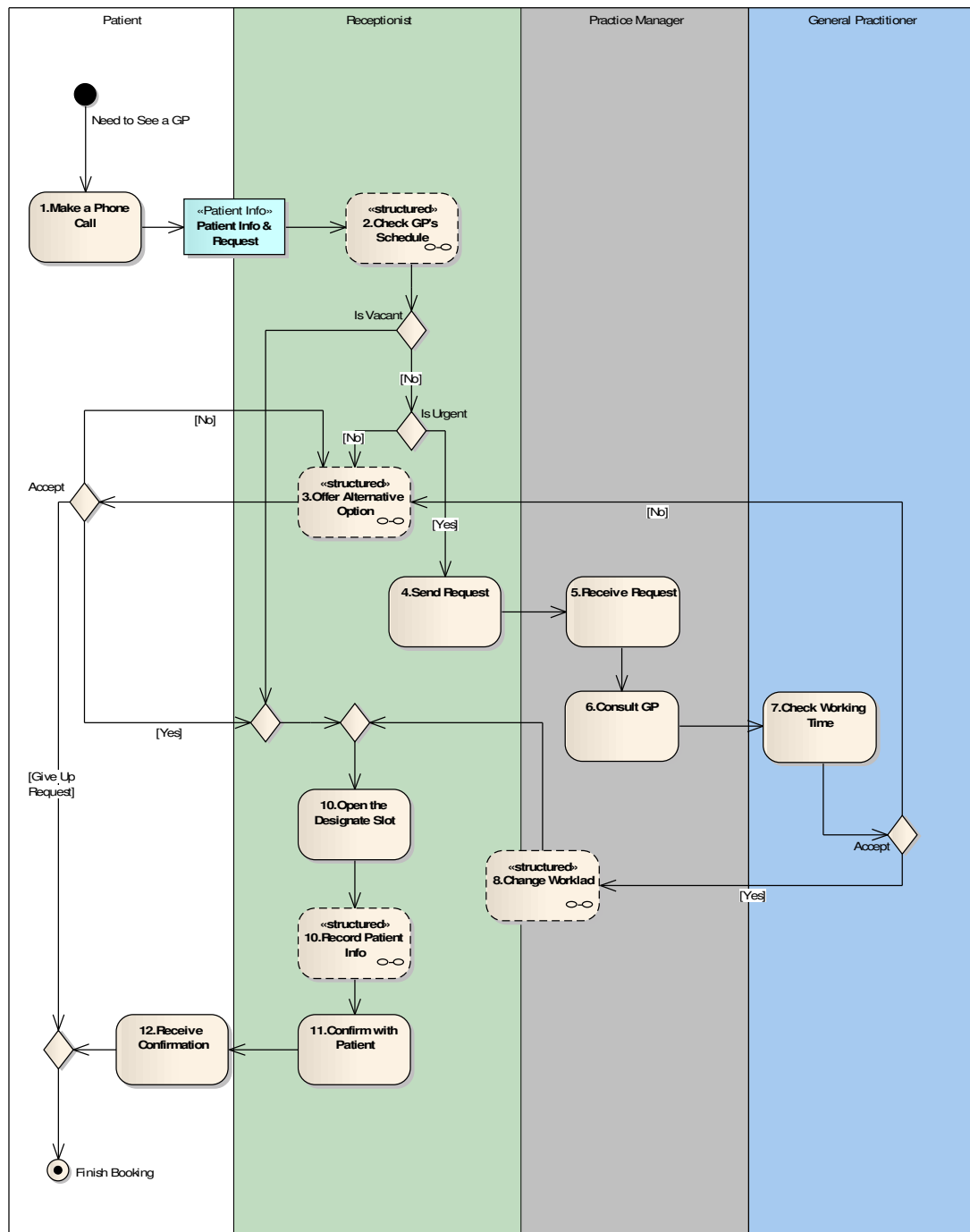
Figure 4-4 Activity Diagram: Overview of the workflow for patient booking

This process starts with the Activity 1: Make a phone call when a patient calls the medical centre to see a GP. A patient is likely pass two messages to the receptionist who answers the phone: (1) the patient's personal information, and (2) a request, which may contain the required time and the required GP. After receiving this patient's message, the receptionist would conduct Activity 2: Check the GP's

schedule so as to pick up a proper time slot that might suit the patient's request. Since this activity involves a series of operations with the existing Health Information System (CIS) used in CHC, the detailed description of the internal operation for this structured activity is presented in Section 4.3.3. If the receptionist has found a suitable time slot for this patient, this receptionist may conduct Activity 9: Open the designated appointment slot; otherwise, he/she needs to decide whether this patient has an urgent issue or not. The CHC has different clinical procedure for normal or urgent patients.

For normal patients, the receptionist would conduct Activity 3: Offer alternative options. If the receptionist failed to offer an appointment in Activity 2, due to the required GP being unavailable or the required time being already taken, some of the patient's requests could not be fulfilled. The solution for this situation is detailed in Section 4.3. 4.

If the receptionist failed to offer an appointment to a patient with an urgent request (in very rare cases), he/she would send a request (Activity 4) to the practice manager. The practice manager would then check the request (Activity 5) and consult with GP (Activity 6) to see if the GP could spend some time to provide urgent service to this patient. If the GP decided to offer a service to this patient, then the practice manager or the receptionist may insert an extra appointment slot on the GP's schedule. This is considered as increasing the GP's workload (Activity 8). If the GP declined to offer an extra appointment, then it is up to the receptionist to offer an alternative appointment from the GP's Schedule. Sometimes the receptionist could directly contact the GP without the practice manager's involvement.

Once the receptionist provided the appointment to the patient according to the person's request and the patient also accepted the arrangement, the receptionist

would open the assigned appointment slot (Activity 9) and record the patient's information (Activity 10) into the corresponding slot. Because this activity (Activity 10) involves a series of operation on the CIS used in CHC, the detailed description of the internal operations in this structured activity will be presented in Section 4.3.5. Afterwards, the receptionist confirmed the appointment with the patient (Activity 11) about the appointment, and the patient was required to remember the confirmation (Activity 12), including the information of when to see whom.

4.3.3   The Receptionist's Workflow of Checking GP's Schedule

In Section 4.3.2, we presented the overall workflow of making an appointment. Checking GP's Schedule is Activity 2 in Figure 4-4. In this section we describe the receptionist's interaction with an existing CIS for the completion of this activity (see Figure 4-5).
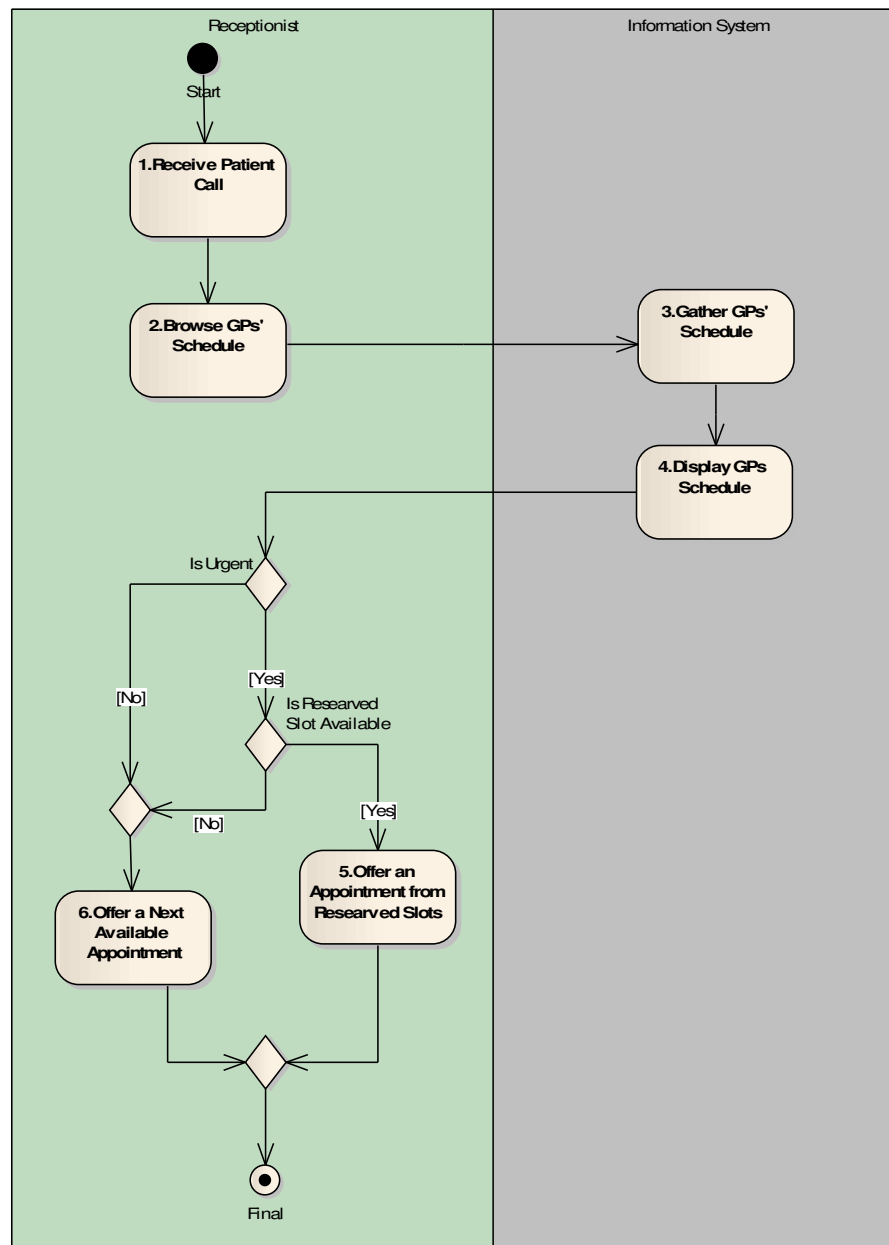
Figure 4-5 Activity Diagram: a detailed workflow of receptionist checking GPs' schedule

This activity started when the receptionist received the patient's phone call (Activity 1), which would contain two messages: personal information and request information. Then the receptionist consulted the CIS to check the GPs' schedules (Activity 2). The CIS gathered all active GPs' schedule from the database (Activity 3), and displayed them on screen (Activity 4). After browsing the schedule organised by the CIS, the receptionist had to decide whether this patient had an urgent request or a regular request. The receptionist would check the availability of the reserved slots (Activity 5). If it was an urgent request and there were reserved appointment slots, the receptionist would pick up a suitable time slot for this patient. Otherwise, the receptionist would offer the next-available time slot to fulfil the patient's appointment request (Activity 6).

In most cases, a patient with an urgent request would demand the closest available appointment. Most GPs' schedules have been fully booked at least for a few days in advance. In order to provide timely service to those patients with urgent request, the practice usually reserves a few slots everyday from GP's schedule, which would only be offered to patients with urgent request.

4.3.4   The Receptionist's Workflow of Offering Alternative Options

A receptionist checking GP's schedule is represented as Activity 3 in Figure 4-4. There is the possibility that the receptionist could not find an appointment that satisfied the patient's demand. There are only three activities involved in this process (see Figure 4-6). The receptionist will need to check the next available appointment for the required GP (usually this patient's family GP) (Activity 1), and the closest appointment to the patient's original request from another GP's schedule (Activity 2). Then the receptionist offers these two alternative options for the patient (Activity 3).
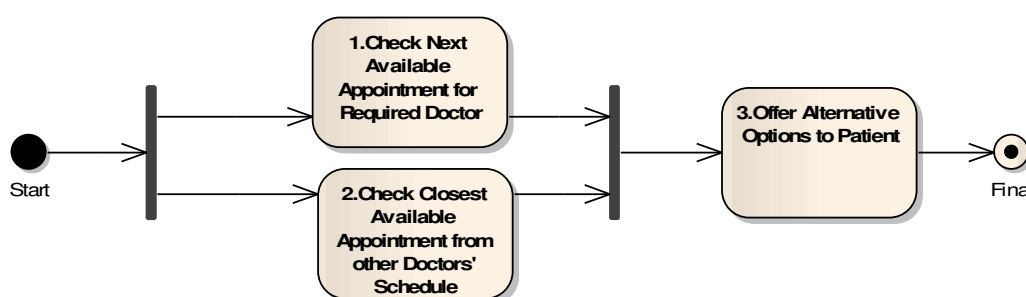
Figure 4-6 Activity Diagram: workflow of offering alternative options to patient

There is a dilemma for the patient to decide either of these two alternative options. If the patient decided to take the option of seeing his own GP, he would probably wait for a long time, which may be harmful for his/her own health. Otherwise, he may get an earlier appointment to see another GP, who would be unfamiliar with his/her medical history, even though this GP could retrieve this patient record from the CIS.

4.3.5   The Receptionist's Workflow of Recording Patient Information

An overview of the activities involved in receptionist recording patient information is presented as Activity 10 in Section 4.3.2 (see Figure 4-4). In this section the detailed workflow and interaction between the receptionist and the CIS are described (see Figure 4-7 next page).
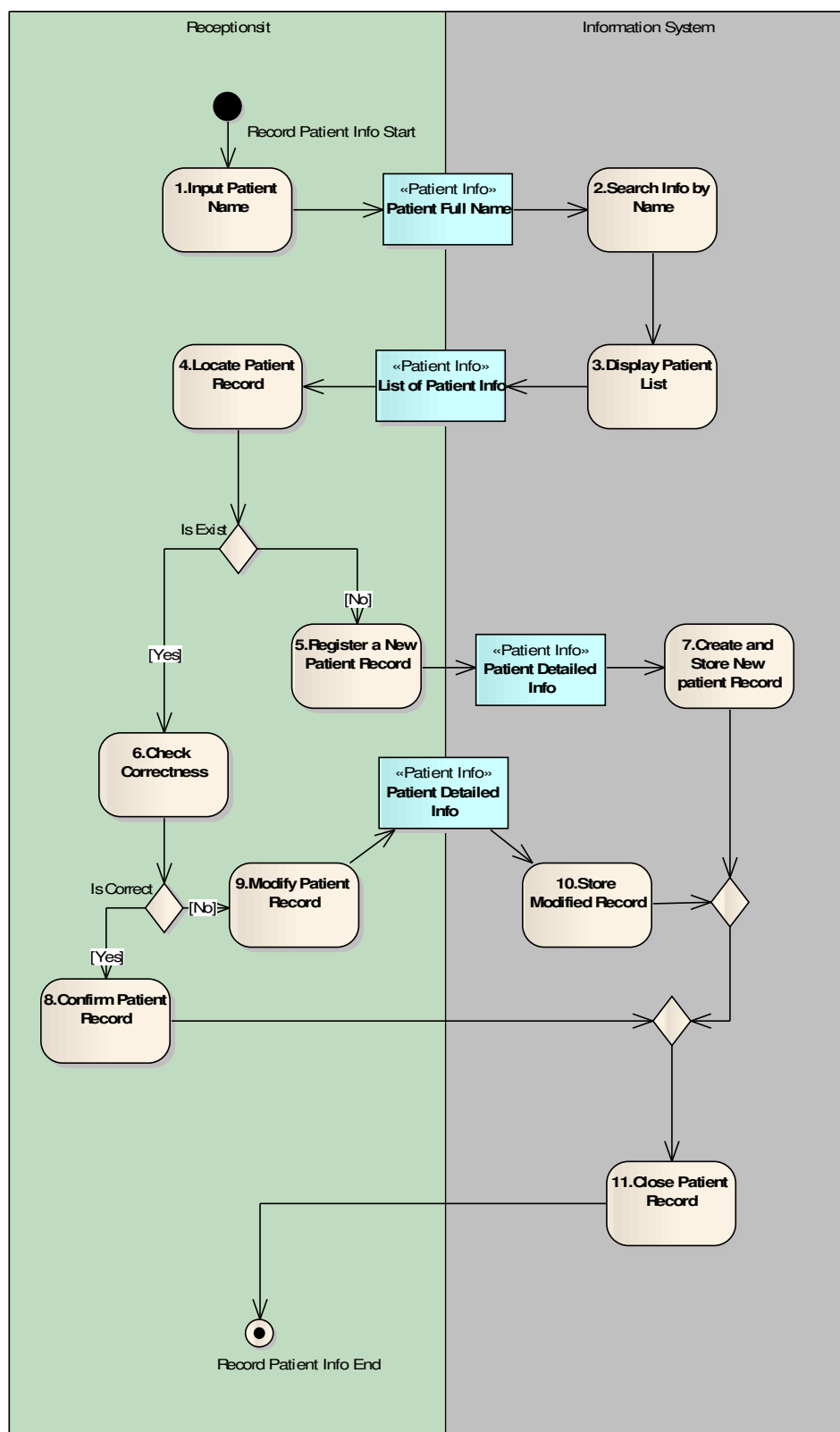
Figure 4-7 Activity Diagram: the receptionist's detailed workflow of recording

patient information in the CIS

After opening an appointment slot, the first activity for the receptionist was to enter the patient's name. The CIS would search all related patients and their records (Activity 2), with the same or similar input from the database. Then it would present all the records to the receptionist (Activity 3). The receptionist will browsed these records to see whether this patient's record already exists in the system or not (Activity 4). If the patient's record was not in the system, this means that this patient is a new patient, and the receptionist should register this patient's detailed information into the system (Activity 5) including name, gender, address, contact number and Medicare number. A new record for this patient was thus entered into the database (Activity 7). If the patient's record was retrieved from the CIS, the receptionist should firstly verify the correctness of the record (Activity 6). If the record was consistent with what the patient expressed, the receptionist only needs to confirm the existing data in the CIS (Activity 8), otherwise, the receptionist would modify the patient's details in the CIS (Activity 9), and the CIS would store this modified record in the database (Activity 10). Finally, as the patient's record was linked with the corresponding time slot on the GP's schedule, it means all necessary data of this appointment had been stored in the CIS; so the patient record would be closed (Activity 11).

4. 4   Data Structure

The purpose of studying data structure of the existing appointment system is to understand the exact information that has been stored in the database to indentify an appointment. The data structure used by the GP's appointment system and AHP's appointment system are described in the Entity-Relationship diagram.
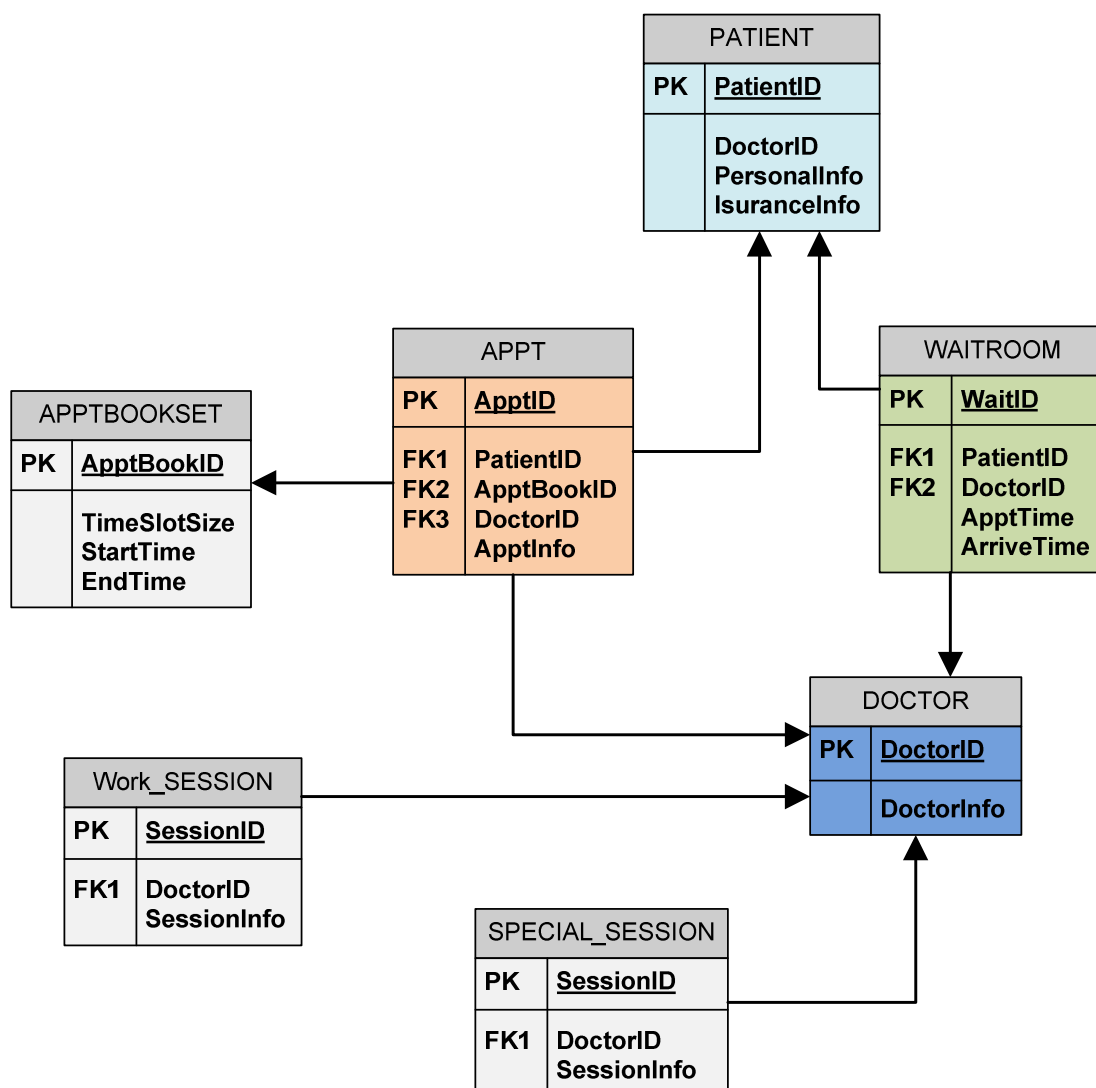
Figure 4-8 E-R Diagram: tables for recording appointment data used by the GP's

appointment system

The GP's appointment system is a dedicated appointment system for health providers. The data structure of the GP's appointment is described in Figure 4-8. There are seven tables used to record the patient's appointment information. A table named PATIENT is used to store patient related data. A table named DOCTOR is used to store doctor related data. A table name APPT is used to record appointment related data. A table named WAITROOM is used to record related data when a patient arrived at the medical centre and registered at the receptionist desk. A table named

APPTBOOKSET is used to decide the size of appointment table. A table named Work_SESSION is used to adjust every doctor's routine working hours, and a table named SPECIAL_SESSION is used to record every doctor's irregular working hours.

egw_cal	
PK	**cal_id**
	cal_uid **cal_title** **cal_description**

egw_cal_dates	
PK **PK**	**cal_id** **cal_start**
	cal_end

egw_cal_repeats	
PK	**cal_id**
	recur_type recur_enddate

egw_cal_holidays	
PK	**hol_id**
	hol_info

egw_cal_user	
PK	**cal_id**
	cal_recur_date **cal_user_info** cal_status
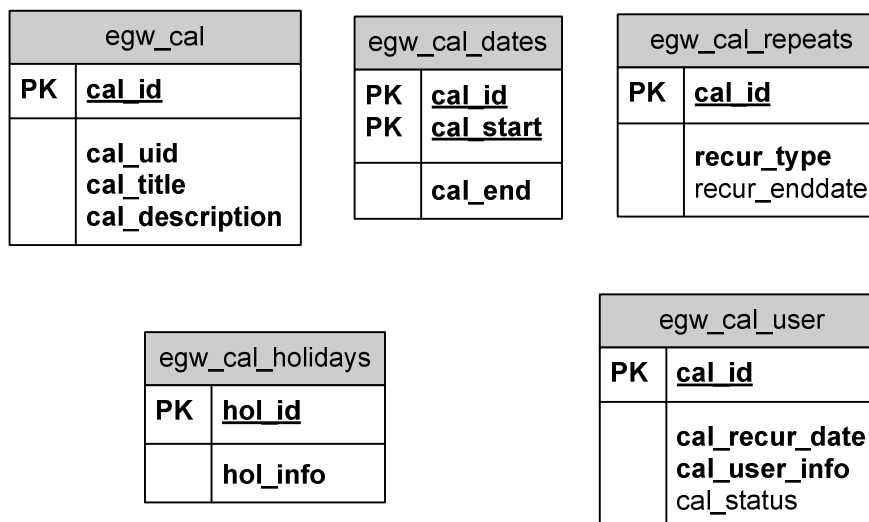
Figure 4-9 E-R Diagram: tables for recording appointment data used by the AHP's appointment system

Contrary to the GP's appointment system, the AHP's appointment system is not specifically designed system for healthcare providers. The data structure (see Figure 4-9) is composed of five isolated tables. A table named *egw_cal* is a centred table used to record the appointment description data. A table named *egw_cal_*dates is used to record the appointment time start and end. A table named *egw_cal_*repeats is used to record the information about some repetitive appointments. A table named *egw_cal_holidays* is used to record holiday related data and a table named *egw_cal_user* is used to recode the user related data.

4. 5 Patient Journey

The purpose of studying patient journey is to understand the appointment process from a patient's perspective. This section outlines the processes a patient has to follow in order to see his/her family GP (Figure 4-10).
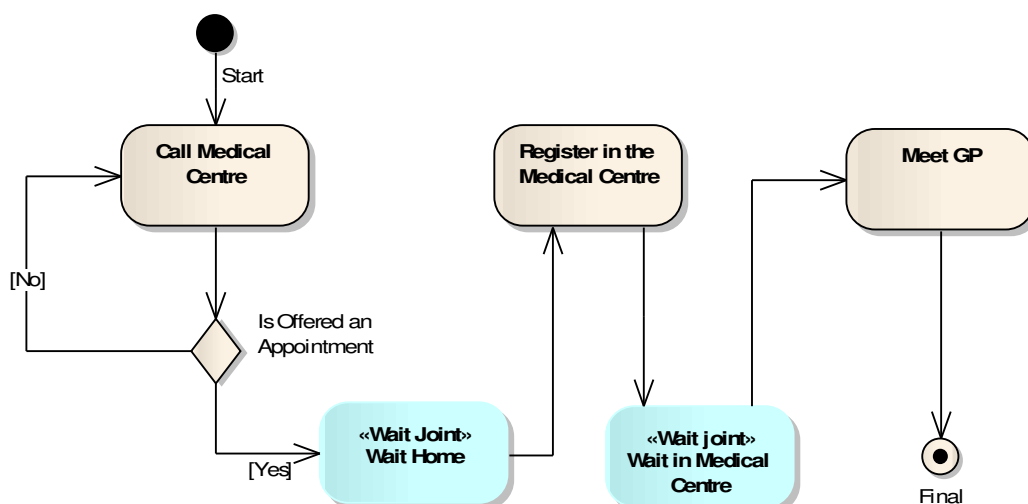
Figure 4-10: Patient Journey to See a GP

When a patient wanted to see a GP, the first thing this patient needed to do, is to call the medical centre and make an appointment with a GP. If this patient is offered an appointment, he/she may wait until the appointment time arrived to see the GP. This is the first Wait Joint (See Figure 4-10), and the duration varied between cases. For a patient with an urgent request, he/she might see the doctor on the same day when he/she called the centre. For a patient with regular request, the duration between the request and the actual visit may depend on the availability of the GP, from a couple of days to a couple of weeks.

On the day of the reserved appointment, the patient needed to register at the reception desk before he/she could see the GP. This patient might experience another Wait Joint, which might take a few minutes or an hour depending on the length of the queue on the day. Generally speaking, an ordinary appointment may last for 10 minutes average. If one appointment exceeds 5 minutes, the following appointment would be delayed for that long. After a short period of waiting, the patient could see his/her GP.

4. 6   The Existing IT Infrastructure in the CHC

The purpose of gaining an understanding of the IT infrastructure in CHC is to understand the organisation's IT environment, which is an important factor in considering the design and implementation of the new appointment system. The following sections will present the information about network, hardware, and software infrastructure in CHC.

4.6.1.1   Network

In Centre Health Complex, Family Healthcare (GP section), Allied Healthcare and Specialists Healthcare were directly managed by the CHC headquarters, so they use the same IT system. The CHC intranet was the network used to maintain the designated systems for these three healthcare facilities and the headquarters (see Figure 4-11).
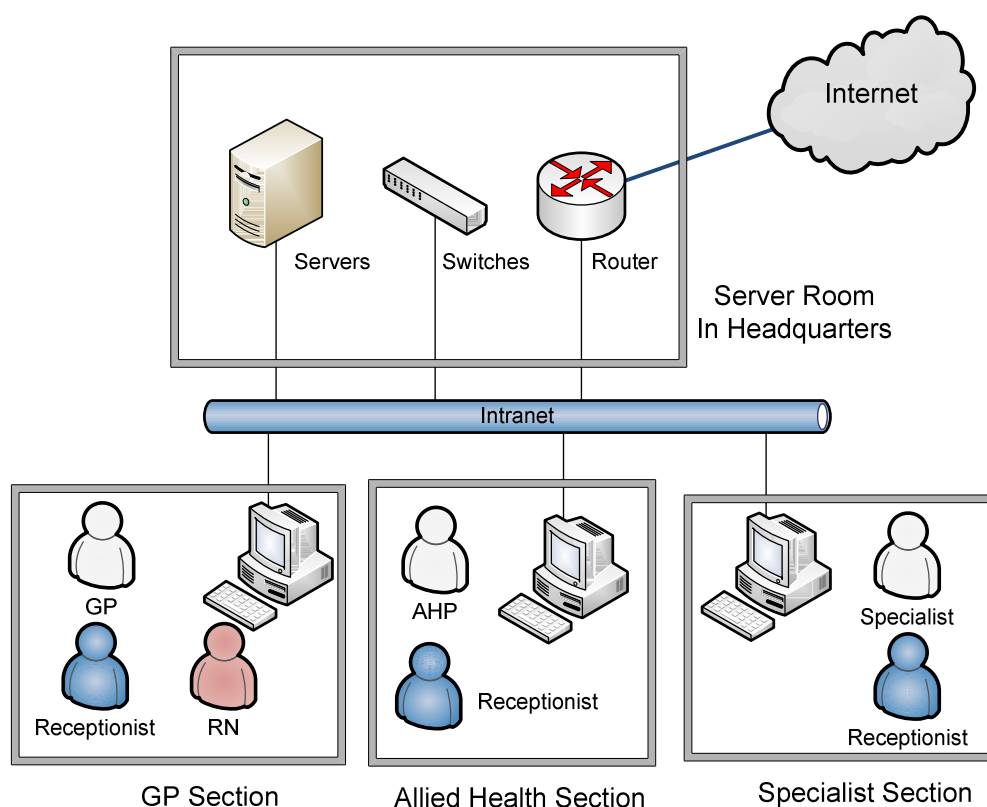
Figure 4-11: The basic network topology in Centre Health Complex.

The server room was located in the head office on the second floor. Servers, switches and Internet dial-up router were all placed in this room. This dial-up router linked CHC with the internet with bandwidth of 20mb/s download and 820kb/s upload speed. The intranet users include users in each section who were GPs, allied health professionals (AHPs), specialists, receptionists and registered nurses (RNs). Their computers were connected with each other though switches in the server room.

4.6.1.2   Software

In the GP section (including GPs, RNs and receptionists), the same applications were shared. The softwares applications included Medical Director 3 and Pracsoft 3. They used a Server-Client Architecture. The client applications were installed on all the computers in the GP section and connected to the server hosted in the head office. This distributed software system had two basic functional modules: an EMR module, which was used by GPs and RNs for recording patients' medical data; and a practice management module, which was generally used by receptionists' and the practice manager for managing patients' appointments and fee statements. Microsoft Windows XP operating system (OS) ran on all these workstations.

There was no specific system for booking and recording patients' records in the workstations used by specialists. Different types of specialists may need different software for their specialty. Workstations in this section just provided software for basic text editing, and Internet browsing. All these computers have installed the Windows XP OS. Workstations in the Allied Health section used a web based booking systems. This system was also hosted in head office and used by allied health professionals and receptionists in this section.

4.6.1.3   The Server and Service

In the head office, there were three servers in the server room named CHA-Eye, CHA-Brain and Linux Server. Each of these servers had been used from different services. The following section describes each one's function:

1. CHA-Eye: PowerEdge4600 (Windows Server 2003 Standard OS)

    This is the domain controller (DC). It was a logical group of computers running versions of the Microsoft Windows operating system that share a central directory database. This central database contained the user accounts and security information for the resources in that domain. Each person who used the computers within a domain received his or her own unique account, or user name. This account could then be assigned access to resources within the domain (Windows Server TechCenter 2003). Therefore, the DC was responsible for managing the users and computers under this domain.

2. CHA-Brain: PowerEdge4600 (Windows Server 2003 Standard OS)

    This windows server runs the server-side electronic medical record application, which is reachable from all of the internal workstations used by GPs, receptionists and practice manager in the CHC. This server side application features a master database for collecting patient data, and several small scale applications that are responsible for downloading patients' exam results from external services.

3. Linux Server: PowerEdge1425

    This server maintains two services: the web booking system for allied health section and Secure Shell (SSH) service, which is a protocol that allows data to be exchanged using a secure channel between two networked devices (Barrett, Silverman et al. 2005). In this case, SSH provides the secure channel, through which IT supporters could make remote configuration to the CHC internal systems.

Despite these three servers placed in the server room, CHC had outsourced its Website which was held on another server outside the organisation. This website

only presented some static pages to describe the services provided in the CHC. It was not linked with the CIS in CHC.

4. 7   Summary

This chapter presented the results of findings of the field study in CHC. These results include a brief study of patient admissions, detailed studies of providers' workflow for booking patients, data structure in the appointment system for recording patient's appointment information, the patient's journey for attending appointments and the existing IT infrastructure report. The weak points analysis presented in the discussion section is based on the details indentified in these studies.

5. PROBLEM ANALYSIS

5. 1 Introduction

In Chapter 4, the second step of system analysis in research Phase1 has been reported. Diagrams were organised to give a detailed view of booking workflow, data structure, patient journey and the existing IT infrastructure in Centre Health Complex (CHC). This chapter reports the findings of the last stage of system analysis in research Phase1: discuss the problems with the exiting appointment system based on the findings presented in Chapter 4. Section 5.2 discusses the necessity of adapting advanced access model to improve patient's access to the health care services in CHC. Section 5.3, 5.4 and 5.5 discuss the barriers of noted in the existing workflow, data structure and IT Infrastructure respectively that the new design needs to overcome to provide better accessibility for patients. The chapter concludes with a summary.

5. 2 Necessity of Adapting Advanced Access Model

The direct impulse for choosing the advanced access model was the problem of long time service delay, as was mentioned in Section 4.2 a brief introduction of patient admission in CHC. That is for some GPs in the CHC, the duration for a patient between making an appointment and attending the consultation reached more than two weeks. For the physiotherapist and the podiatrist in the AHP section, patients would have to wait for more than a month to get a routine appointment. As was described in Figure 4-1, the long backlogs had an ascendant trend over the three years, although the delay might fluctuate within a short period. However, the amount of care provided by these three providers was maintained at a stable level, which means that the practice did not have any strategy to intervene or attempt to improve the provision of appointments. This was caused by the limitations of the current

appointment model, which did not provide any guidelines for sustaining patients' accessibility. Moreover, the existing appointment system is incapable of providing accurate information about service delays, service shortages and strategies for reducing the practice backlogs. The Advanced Access model presented here is an up-to-date appointment model, which solves the problem of timely patients' access to health care services. The general idea of Advanced Access model can be described as to a mean of eliminating service delays and improving patient's access by (1) setting up a suitable access target; (2) monitoring patients' request; and (3) intervening in service provision. Hence, the Advanced Access model is applied in the design of Advanced Appointment System to solve the challenge of patient's access to healthcare services in CHC.

5. 3 The Problem with Accessing Different health Service Providers

We have described the patient journey in Section 4.5. A patient would spend from few days to a few weeks waiting to see a GP or an AHP, as was indicated by their backlogs. For some GPs in CHC, a patient had to wait more than two weeks to get a routine appointment. But a patient would have to wait longer than this if waiting an AHP, approximately four weeks for a physiotherapist and twelve weeks for a podiatrist.

For example, there is an elderly patient with chronic disease who wants to receive an enhanced primary care (EPC) program with five services in a year. The flow for this patient to complete this program is presented in figure 5-1(see next page). This patient has to spend 2 weeks waiting for the initial appointment, at which the GP sets out a chronic disease management plan. After this, the patient would wait 12 weeks for the first service from the podiatrist. Each of the four following visits needs the same length of waiting time (12 weeks). Added the 2 weeks for the review appointment with the GP, this patient could spend a total of 64 weeks for this EPC service. Moreover, this is the least amount of waiting time provided that this patient

makes a reservation immediately after each visit. While some professionals may argue that visiting five times in a year is not sufficient for this patient, the patient in this situation has difficulty making enough appointments for four services in a year.
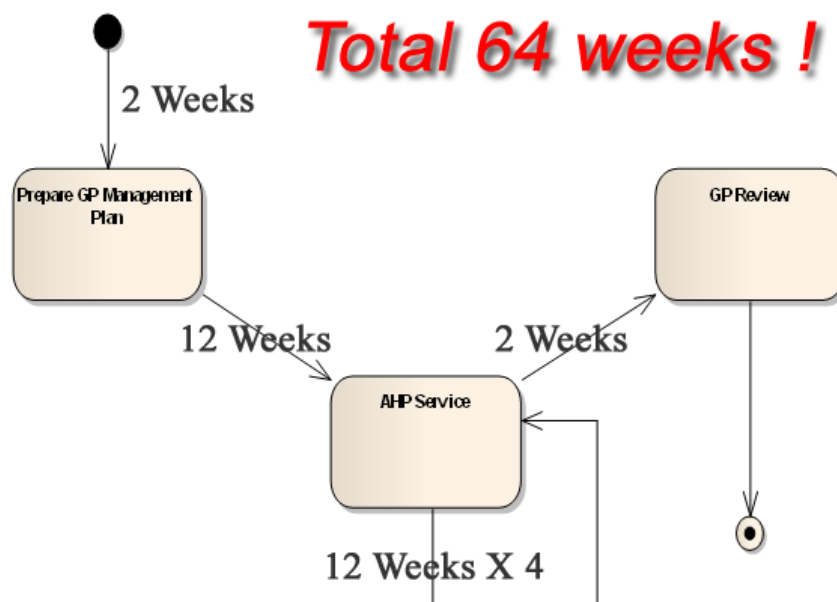
Figure 5-1: Overall Waiting Time to Receive 5 Times EPC service from Podiatry in

CHC

This case suggests that the changes needed for patients' access to services to be improved depend on eliminating the backlogs of both providers. Besides the problem of access, we have found that GPs usually do not know the AHP's schedule before referring their patients to an AHP, even though they were co-located in the same building. It is likely that the GP who served the old patient in the case mentioned above could have referred this patient to another podiatrist with a shorter backlog, if he/she knew the booking status of every podiatrist in CHC.

5. 4 The Barriers with the Existing Appointment System

To implement the Advanced Access model in the practice, the limited capability of the existing appointment system is the major barrier. The workflow of the patient

booking system was presented in Section 4.2.1 to highlight the cooperation needed among receptionist, practice manager and GP to make an appointment for a patient. After carefully analysing this flow, three major barriers were identified in the existing appointment system. This system limits the practice's ability to: set access targets, monitor patients' requests and intervene in the practice's appointment provision or supply. The following sections present the three barriers.

5.4.1   The Barriers at Data Entry Point

The workflow for patient's making a booking, which we presented in Section 4.2.1, can be simplified into two phases: to checking GP's schedule and to arranging patients in the schedule. The receptionist firstly checked the availability of a GP's schedule, and then arranged this patient information according to the available schedule. If there was no time slot to suit this patient, the receptionist may not make any appointment for the patient if the later refused to take an alternative appointment. In such case, it appears that the receptionist does not need to record any information about this encounter. However, this process has fatal problems in meeting patient's needs.

For example, Dr. Lightman can serve 30 patients per day, but he does not take pre-scheduled appointments. There is a burst of influenza and 45 patients need to see Dr. Lightman on one day. Obviously there would be 15 patients who could not see this GP. The demand for the next day's service from Dr. Lightman is 45 patients. Does it mean that the demand for Dr Lightman is now 45 patients per day? The answer is 'No. The patients coming to see Dr. Lightman may include the patients, who did not get the opportunity to see him the previous day, as well as the patients that he sees regularly and some new patients.
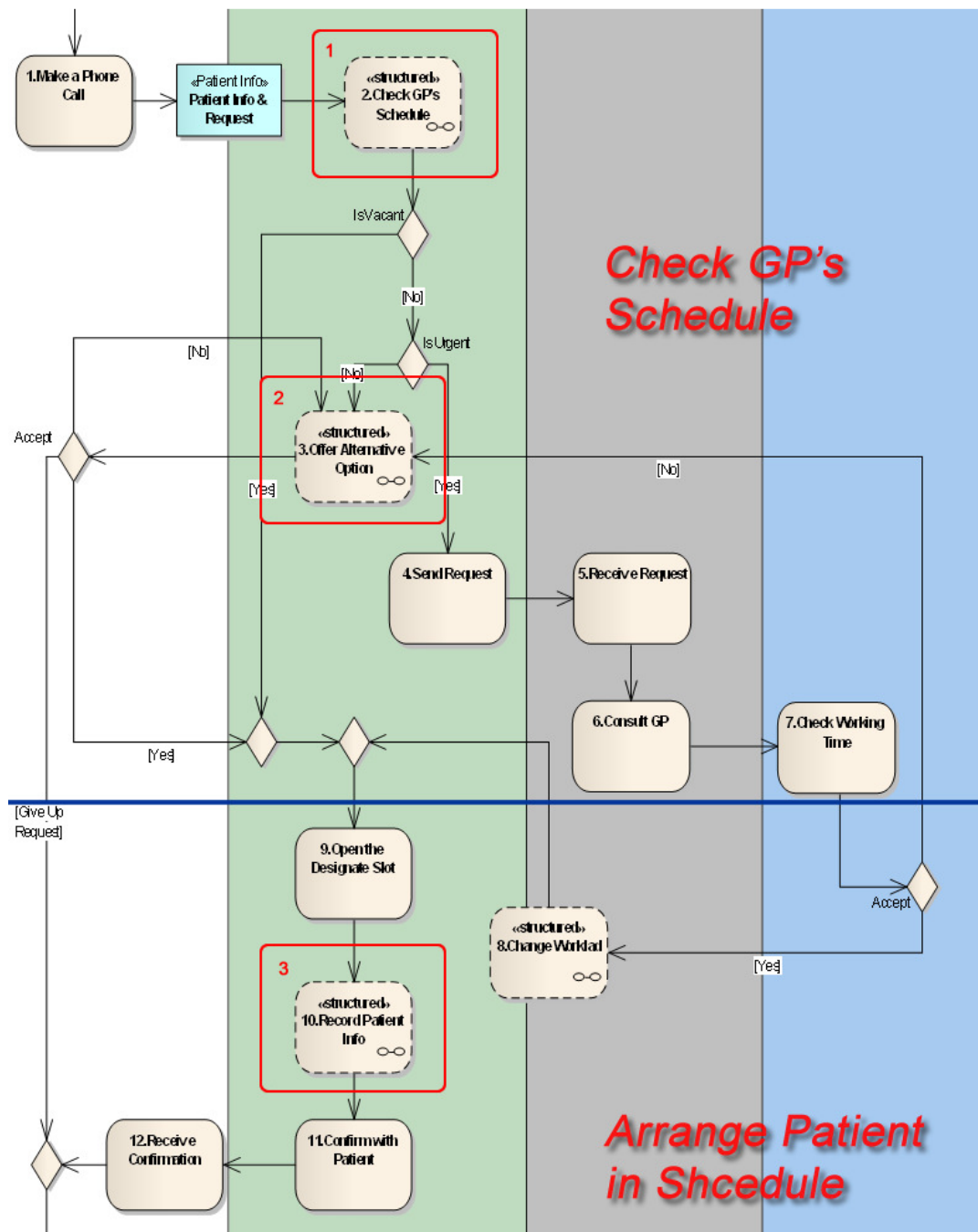
Figure 5-2 (Segment of Figure 4-4): Weakness identified with data entry point in

patient booking process

Earlier discussion highlighted the three structured activities (see in Figure 5-2) in the

interaction between the between receptionist and CIS in CHC. First, the receptionist

checks a GP's schedule to find an available time slot, or offer an alternative

arrangement if the requested time slot has been occupied. So far the receptionist has

only browsed the GP's schedule data recorded in CIS; only when the agreement about the appointment time has been reached, would the receptionist enter the patient's information into the CIS. If the agreement had never been reached and the patient refused all of the offerings, it is impossible for the clinic to identify on which day and which patients were not given an appointment.

Because of this practice, the information about which patients were not able to access the health service is missing. The failure to record the actual patient request on a daily basis means that the whole booking process does not have a mechanism to measure the demand. It is for this reason that in some practice, the receptionist and practice manager have to spend extra time recording patient requests on paper. It is necessary to modify the data recording activity, so that the practice can manage the patient data estimate the trends and plan the future service provision. Therefore, it is necessary to modify this data recording protocol to facilitate a means of accurately measuring the patient demand on each day, which would help the practice to estimate patient access trends and assist in planning for the future service provision.

5.4.2   The Barriers for Service Performance Measurement

During the process of checking the GP's schedule, the information that the receptionist captured from the CIS is was limited to the provider's time table. Neither GP's nor patient's information was displayed to the receptionist before he/she arranges for a patient to see a GP in a specific time slot. Therefore, the receptionist would not know the number of appointments that were taken, nor the number of appointments that were still available for both individual GP and the whole CHC.

The above analysis suggests that it is necessary to place a built-in system performance monitoring module in the CIS to present the user with real-time statics result of practice performance. This will give the receptionist and practice manager

sufficient information about GPs and patients before arranging an appointment for a patient.

5.4.3 The Barriers for Managing Patient Appointment

In order to reduce patient waiting time, we have to balance supply and demand on a daily basis. If patient demand has been recorded, a dynamic way to manage GP's supply (in other words, workload) is required because patient demand is not a constant, it is fluctuate daily. However, a doctor's schedule is usually static in the existing CIS (in Figure 5-5). The appointment slots are sorted into two categories: opened appointment slots and carved out slots. Opened appointment slots are for all patients and the carved out slots are reserved for patients with urgent request.

	Mon	Tue	Wed	Thu	Fri
8:30					
9:30		Opened Appointment			
10:30					
11:30		Noon Break			
13:30					
14:30		Carved Out Slots			
15:30					
16:30					

Figure 5-3: Carved out appointment schedule applied in the clinic

The workload of a full-time GP reflected on this schedule is fixed. The principle of using this booking schedule will easily cause service delays. For example, once a

GP's schedule on a specific day has been fixed, patient appointments can only be arranged in the carved out slots. If patients' demands on that day exceed the provider's supply within the scheduled time, then the exceeded demands will be postponed into the future schedule, which causes service delay. With time, the postponed appointments form a long list of backlogged appointments, which seriously impedes patients' access to health care services. Previous studies indicate that missed appointments occurred more frequently when patients experience long waiting time (Belardi, Weir et al. 2004; Knight, Padgett et al. 2005; Mehrotra, Keehl-Markowitz et al. 2008), which wastes the GP's precious time slot allocated to this patient. It also blocks another patient's access to the services. In the long run, the recurrence of this situation will eventually cause the deterioration of the supply of health care services (Murray and Berwick 2003; Martin, Perfect et al. 2005).
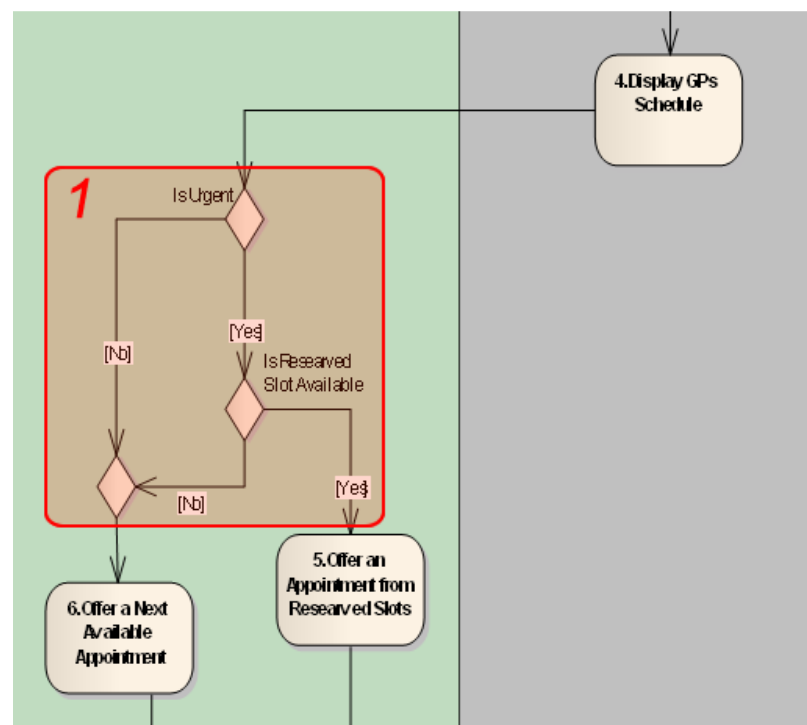
Figure 5-4 (Segment of Figure 4-5): The weakness with the principle to arrange an appointment for a patient (1)

To eliminate the backlog, develop contingency plans need to be developed to increase the efficiency of supply, especially of bottlenecked resources. However, picking up a suitable appointment for a patient was mainly decided by urgency of the patient's need and if and the availability of a time slot, as shown in the oval 1 in figure 5-4. In order to provide better access for patient, the practice needs to create extra capacity in case there is an upsurge in requests on certain days, or there is a shortage of supply in the future. As shown in Figure 4-1, service delay increased drastically when three GPs was absence from the CHC. Moreover, shortly after the providers come back, the service delay could hardly decrease back to the level when they left. If the accessibility can be guaranteed in the practice, continuity is another key factor in arranging patient appointments. A similar problem is also reflected in the process of providing an alternative appointment for a patient as shown in oval 2 of figure 5-5 (next page).
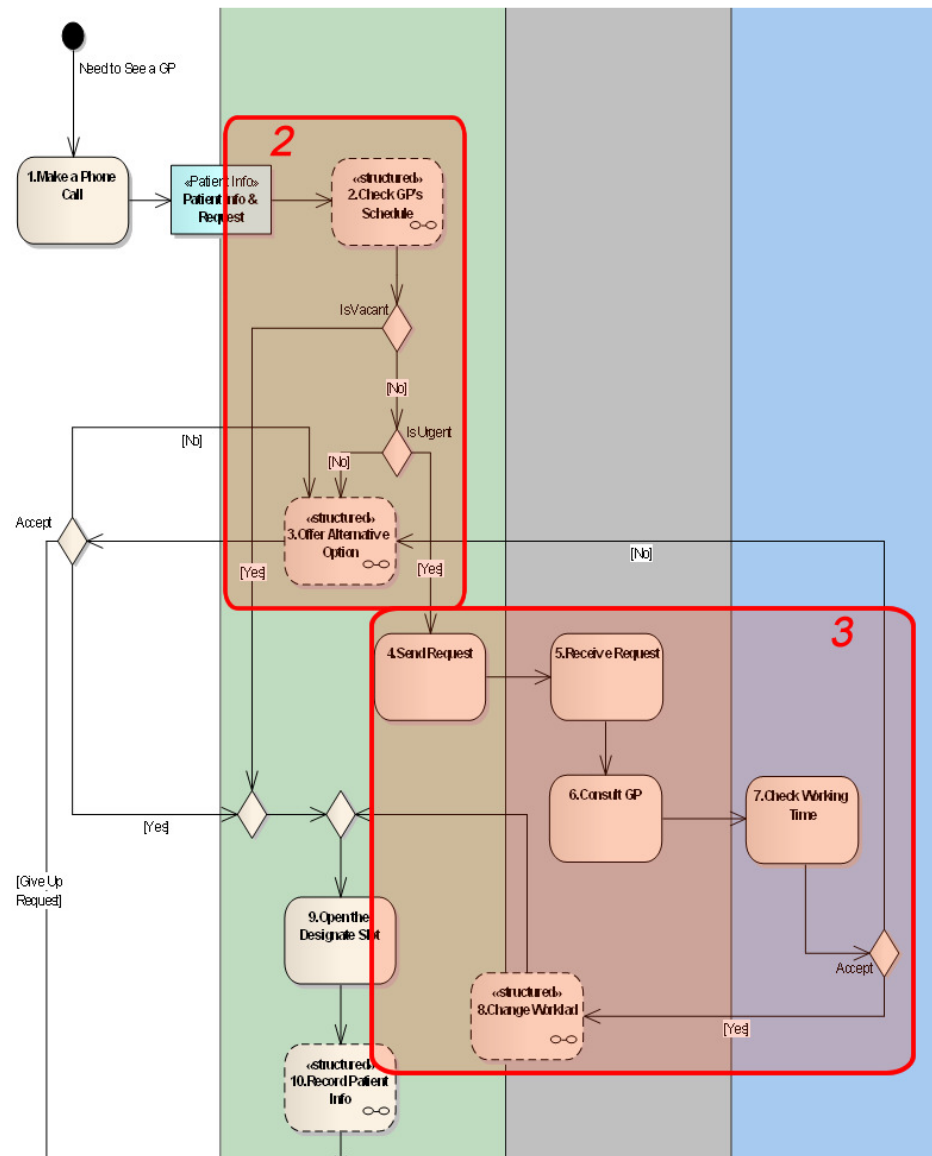
Figure 5-5 (Segment of Figure 4-4): The weakness with the principle to arrange an

appointment for a patient (2)

Beside this, if the practice were to frequently alter a GP's workload, the process of applying for an extra appointment with a GP would become a burden. Because intervening in providers' supply is a major approach for reducing the provider's backlog, with the existing workflow, both the receptionist and the practice manager will be busy working on coordinating the GPs' working hours.

There are two lessons learned from above. First, the static schedule does not suit for managing service supply and patient demand, when GPs are required to provide

increased amount of service for meeting patients' request and eliminating services backlogs. A better designed schedule, which could flexibly manage GP's workload, and provide convenient process to manage this schedule is required. Second, an insufficient capacity to monitoring service performance and providing easy-to-read booking information to the receptionist make it difficult to implement standardised approach to arranging patient appointments.

5. 5   The Barriers in IT Infrastructure

The IT infrastructure was presented in Section 4.5. In this section we will identify the barriers, which reside within the architecture of the existing CIS. First, the weak points we have mentioned in Section 4.3.2 suggests that the schedule data were not shared in the CHC, even though GP and Allied Health shared the same Intranet. Applications used by different sections are isolated from each other (see Figure 5-6 next page).
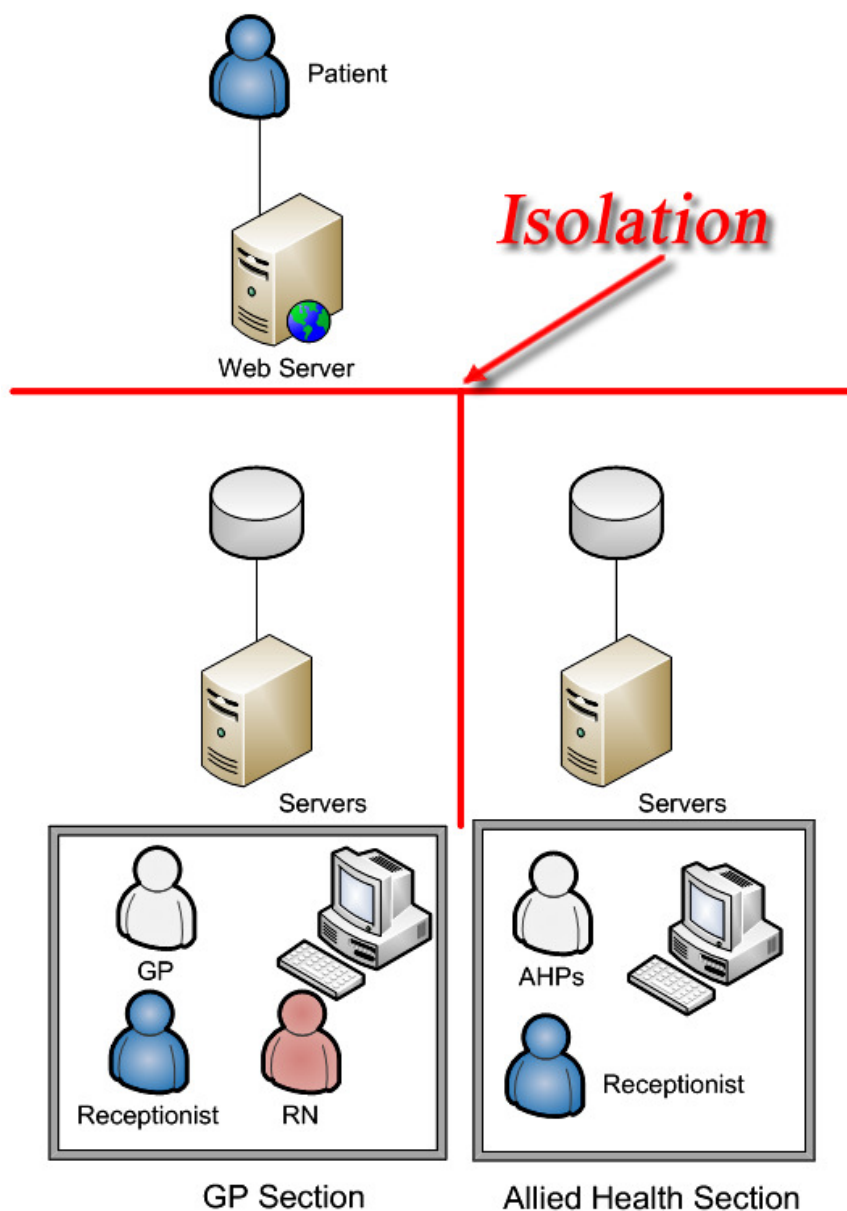
Figure 5-6: GP section, Allied Health Section and Website in CHC are isolated from

each other

Secondly, the purpose of the CHC's building a Website was to provide an information service for patients; however, this website was isolated from the internal system used in CHC either. It was not that these entities could not connect with each other physically; the problem was that there were no integrated services provided to both providers and patients.

Moreover, the existing booking process had heavily relied on the telephone service, and most phone calls were happened between 9am and 11am. Some patients did get timely healthcare services because their request could not get to the receptionist through the phone call. This issue was also mentioned in England (Pope, Banks et al. 2008). It is recommended that the CHC can offer web-based booking service as an alternative to make appointment. This system may also facilitate the patients to retrieve their reservation information issue in case they forget the time of the appointment.

5. 6 Summary

This chapter present the discussion of findings and results we presented in Chapter 5. The focus was to identify the problems of the existing booking system. The identified problems included (1) the drawbacks regarding the patient data entry point, which is incapable of recording the patients' request; (2) providing user sufficient information for the user, for understanding appointment status, (3) providing clinical guidelines to the user for arranging appointments to patients; and (4) the system inability of sharing GP's schedule among different providers. These barriers constitute the requirements for designing a new appointment system. The design of the proposed appointment system, which aims to improve patients' access, is presented in the following chapter.

6. SYSTEM DESIGN

6. 1   Introduction

This chapter presents in detail the results of the findings in research Phase2: System Design. Section 6.2 presents the design of the appointment system modules. These modules are designed for managing patient demand, provider's supply, monitoring service performance and providing contingency strategies. They are tailored to solve the problems identified in Chapter 5. Section 6.3 proposes a design of an integrated service structure based on web services. This structure enables the information sharing amongst isolated applications used by different providers and between providers and patients. Section 6.4 discusses the design of system workflow by assembling the modules into an appointment system. Section 6.5 presents the design of interactions among the system components. The chapter concludes with a summary.

6. 2   The Design of Appointment System Modules

The core components of our proposed appointment system are composed of six elements (see Figure 6-1) in managing patient appointment: a system interface, a data repository, a request module, a performance module, a strategy module and a scheduling module.
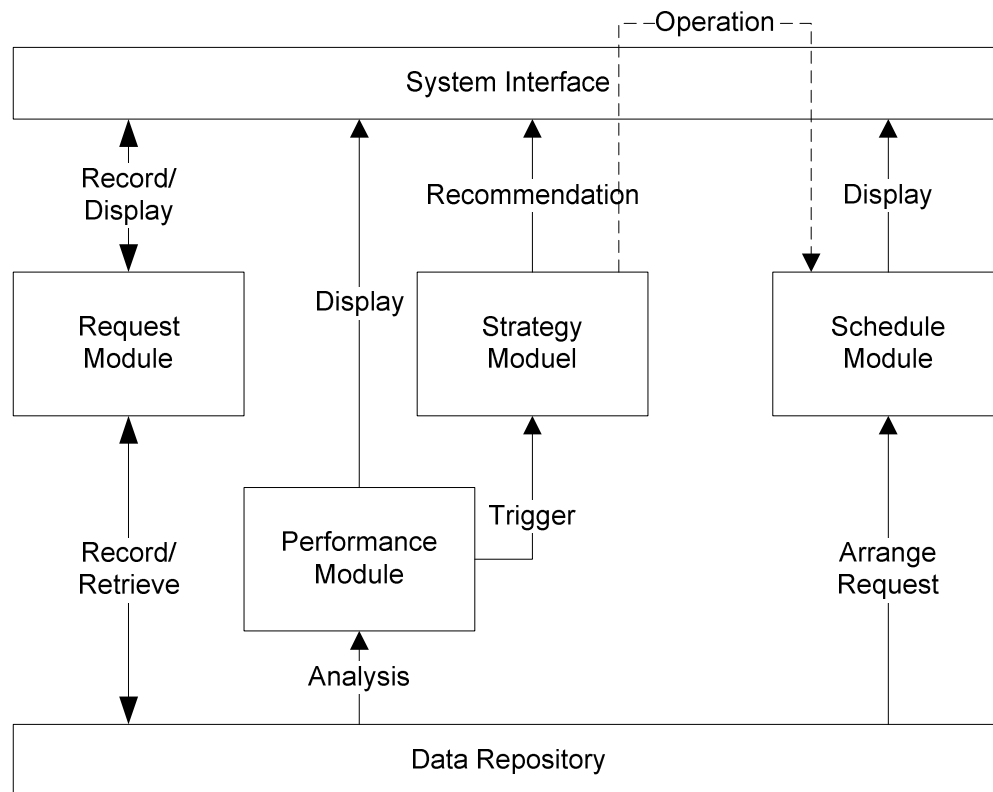
Figure 6-1: Six elements of the proposed appointment system

The Interface provides functionalities to exchange information with end users. The data repository is used to store all the relevant data that are used. Between them there are four modules. The request module is used to calculate patients' demand by tracing patients' everyday requests and sorting these requests in different categories. Basically, the patient requests are entered by the user from the system interface; the request module classifies these requests and stores them in the data repository. If a request already exists in the data repository, the module can retrieve this request and display it on the system interface. The performance module checks the practice performance based on the extent of satisfaction of the demand. If the satisfaction level is below a defined threshold, the performance module will trigger the strategy module to adjust the strategy for patient appointment. Activated by the performance module, the strategy module will provide recommendations to assist the user to

manually make appointments in light of the need of equalising demand and supply. The scheduling module is used to dynamically manage provider's workload, arrange patient requests with appointments and display providers' schedule. The following sections detail the functions of each module.

6.2.1 Request Module

In order to solve the problem of not recording patient demand at the entry point, as was described in Section 5.3.1, the request module was to record patient information at the first step. This module is used to calculate the number of patient demands by tracing the processing of a patient's request in three states: booked appointment, pending request and discarded request (see Figure 6-2). There are three reasons for tracing these requests: First, the practice aims to satisfy each patient's request for an appointment on the day they want it. Tracing each patient's request can help the practice to find the real demand for each service provider on a daily basis. Second, classifying a patient's demand into different categories can help the practice to estimate the types and number of services needed by patients. Third, finding out the ratio of demands that have been fulfilled can enable the practice to understand the gap between the demand and supply.
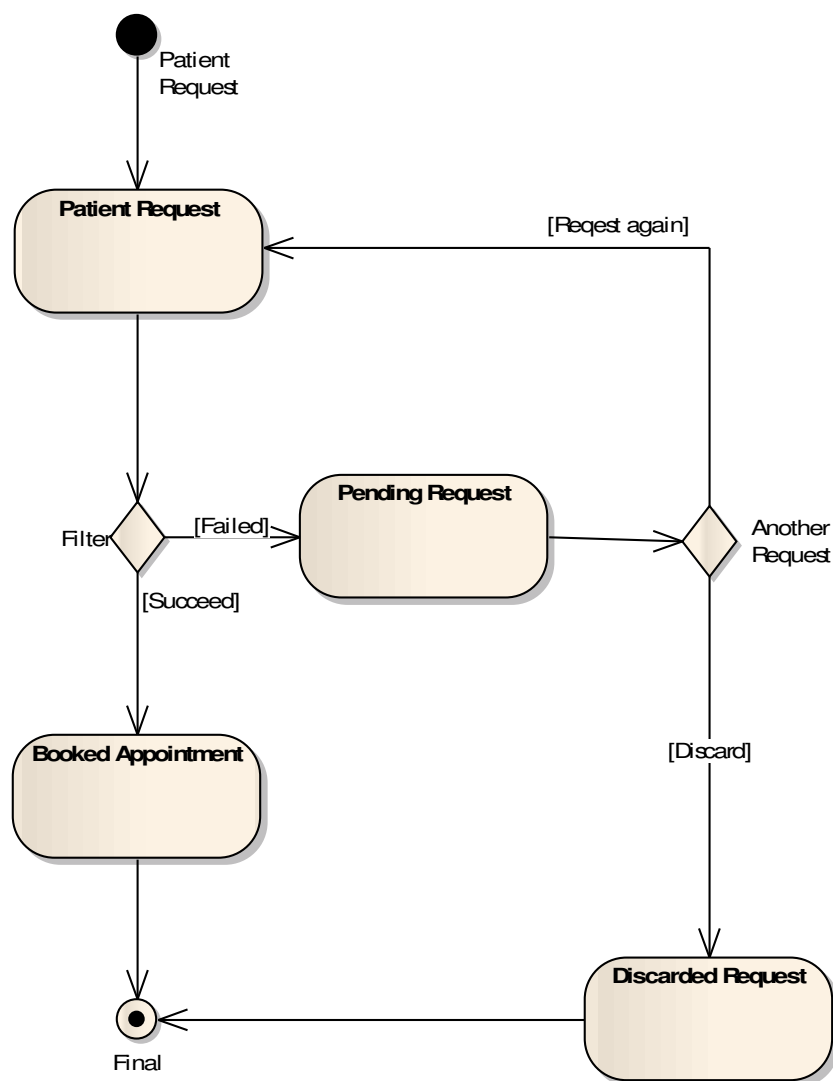
Figure 6-2: The three states of a patient's request for seeing Dr. Lightman and the transaction processes amongst the three states.

In order to accurately assess the patient's demand for Dr. Lightman, for whom the case was described in Section 5.3.1, his patient requests were classified into three states: (1) booked appointment if the patient is offered an appointment; (2) pending request (or unsatisfied request), a middle state, if the patient is not offered an appointment, but wish to call back to fulfil this request; and (3) discarded request if the patient gives up this request. Figure 5-2 describes these three patient request states and the relationships amongst them for seeing Dr. Lightman on a day.

The following 4 formula describes the method to figure out the daily demand, overall demand, fulfilled demand and service gaps in the practice. Both demand and request are measured by the number of appointments:

1. Demand (one day) = Requests (one day) – Pending Request.

This formula suggests that demand on a specific day equals all the patients' requests on that day minus the number of patients' requests that were not fulfilled before and left in the pending list.

2. Demand (all) $= \sum_{i=0}^{n}$ Demand(day i) = Requests (all) – Pending Request (all).

This formula suggests that overall demand during a period equals the summation of daily demand on everyday during this period. That is a summation of each day of patients' requests minus the summation of every day of patients' requests that were not fulfilled before and left in the pending list. Parameter i stands for the index of a specific day, and the n stands for the number of days in that period.

3. Fulfilled Demand (one day) = Offered Appointments – Offered Appointments to the pending query.

This formulate states that fulfilled demand on a specific day equals all the appointments offered to patients on that day minus the number of appointments that were given to the patient's pending requests. The value of fulfilled demand on one day can reflect the efficiency of service provided to patients, because it tells the number of appointments, which have been occupied to remedy the previous requests short-fall and used for today's requests.

4. Service Gap (all) = Demand (all) – Booked Appointment (all)

This formula indicates that the service gap, in other words appointment shortage, equals all patient demand minus the number of appointments provided to the patients requesting the service.

6.2.2   Schedule Module

Recording patients' daily demand helps to estimate future supply; however, the estimated supply may not match the true demand on a particular day. If the estimated demand is lower than the actual demand, then extra capacity of supply needs to be established to match the demand (Gupta, Potthoff et al. 2006). In the example above, it is desirable for the extra capacity to be in place to match the 15 extra demands for Dr. Lightman on that particular day. The barrier for managing patient appointment was also addressed in Section 4.3.1.3. Although it is possible to put in extra capacity to handle the increasing demand, receptionists and the practice manager have to frequently negotiate with providers about adding new patients to the list, since providers' worry that the demand is infinite; therefore, we propose a Schedule module to flexibly manage providers' working hour.

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
8:30							
9:30			*Standard Session*				
10:30							
11:30			Noon Break				
13:30							
14:30							
15:30			*Extra Session*				
16:30							
17:30			*Optional Hours*				

Figure 6-3: Redesign of the provider's schedule to flexibly manage providers'

working hour

The Schedule module could sort provider's capacity into two categories: standard capacity and potential capacity. Standard capacity refers to the consultation that the providers can supply within their standard working session. Potential capacity is the quantity of consultation supplied on providers' extra time including optional hours after standard session and extra session during holidays (circled in Figure 6-3). In contrast to the traditional schedule (described in Section 5.3.3), the carved-out slots for urgent patients are opened to every required patient. Other than giving priority to urgent patients in the traditional schedule, the new schedule tries to balance the demand and supply on a daily basis, so that every patient is able to receive timely service. This schedule works like this: by default the potential capacity is not displayed on a provider's schedule, but they are available when there is a shortage of supply and the owner of schedule grants receptionist's access to the optional hour or extra session. The reservation of the potential capacity is important for a practice to

maintain the balance between demand and supply on a daily basis. This can reduce the backlog in the short term but may increase the workload of service suppliers. The size of the provider's capacity is managed by Schedule module; however, how could this capacity be decided is determined by the rules from the Strategy module once been triggered by the Performance module (see Figure 6-1) and approved by the end user.

6.2.3 Performance Module

The Performance module monitors the service's performance in the practice, which is measured according to the three targets of the Advanced Access model: increasing accessibility and continuity of care for patients and balancing workload for service providers, as mentioned in the introduction section. Different practices have different requirements as regards service accessibility (e.g. same-day access or 48-hours access) (Campbell, Ramsay et al. 2005; Mitchell and Mitchell 2008) and continuity (individual continuity or group continuity) (Salisbury, Sampson et al. 2009) and flexibility of workload (Ahluwalia, Offredy et al. 2005). This requires the practice to set up the boundaries and thresholds for each of these attributes. Once these practice "rules" are determined the Performance module will be able to effectively execute its function of monitoring the performance of a practice and sending alarms to the system when the set-up rules and standards of performance are violated. The detailed description of each attribute was listed in the following sub sections.

6.2.3.1 Measuring Accessibility

The accessibility can be measured from two perspectives: one is the proportion of patients who were given appointments; the other one is the delay that patients have to experience in the practice.

1. Measuring the ratio of patients' access to primary care service

The ratio of patients who were given appointments can be easily measured by calculating the result of booked appointments divided by the number of request.

$$\text{Access Rate} = \frac{\text{Booked appointments}}{\text{Patient Demand}}$$

This formula is very important to the non pre-scheduling practice. Since patients were not allowed to make appointment more than two days in advance in some practice, every patient who booked an appointment could receive very timely service, except those who were not given an appointment.

2. Measuring the service delay

The status of service delay can be measured in two ways; one is a static measurement, which is taken once every working day. The other one is a real-time measurement. They are designed for different purposes; the static measurement is used for tracking the fluctuating of accessibility of service provided to patients, but the real-time one is used to trigger the strategy module for the purpose of dynamic management.

The static measurement is designed to record every provider's third available appointment once every day. For full time provider, this data will be measured every 4pm of the working day; and for a part-time provider, this data will be measured 1 hour before the end of this working day. Not only will the individual provider's data be recorded: the third next available appointment to the practice is also recorded to reflect the availability of the whole medical centre at 4pm of the working day.

The other way to measure real-time delay is also based on the third next available appointment method, but only the individual provider's accessibility will be measured. As indicated in Figure 6-4, the status of delay for a provider is divided into four zones indicating for different level of accessibility; named high

performance zone, medium performance zone, low performance zone and oversize backlogs.
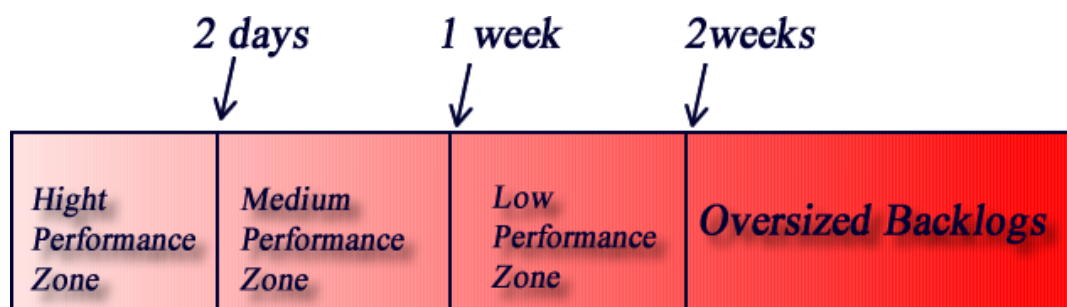
Figure 6-4: Four split zones to show different levels of performance of accessibility

If the status of delay for this provider is no more than 2 working days, which is the commonly accepted access target in the UK to guarantee the high quality of accessibility, the performance of the provider is considered to be at a high level. If the delay is between 2 days and 1 week (depending on the working day of the week), the performance of accessibility to this provider is considered to be at a medium level. If the delay is between 1 week and 2 weeks, the performance of accessibility to this provider is considered to be at a low level. If the patient has to wait more than 2 weeks to see this provider, the backlog for this provider is considered to be oversized.

6.2.3.2   Measuring Continuity

The continuity of care is measured from two perspectives. One is the patient continuity, which means an individual patient is offered an appointment to see his/her own provider or providers whom she/he requested; and the other one is a provider's continuity that is the ratio of one provider's patients who are able to see him/her and those whose requests have not been fulfilled.

Both longitudinal continuity and group continuity for a patient are considered for measurement, as a considerable number of patients might have been treated by more

than one provider, any one of these providers being familiar with his/her illness. In order to doing this, a patient is associated with one or several providers in the CHC. Anytime this patient is offered an appointment to his/her own provider (or one of his/her own providers), the continuity calculator will add this encounter. To display to the user, the continuity for this patient is calculated by the following formula:

$$\textbf{Patient Continuity} = \frac{\textbf{Number of appointments to see own GP}}{\textbf{All appointments}}$$

The score of the patient's continuity equals the number of appointments he/she is given to see his/her own provider divided by the number of all appointments that have been offered.

The provider's continuity is calculated as the following formula:

$$\textbf{GP's Continuity} = \frac{\textbf{Number of appointments this GP offered to own patients}}{\textbf{Number of appointments offered to this GP's patients}}$$

The provider's continuity equals the number of appointments he/she offered to his/her own patients divided by the total number of appointment this provider offered to his/her patients (some of the appointments may be offered by other providers in the CHC).

Both patient continuity and the provider's continuity are recorded once an appointment has been fulfilled.

6.2.3.3   Measuring Workload

Since the provider's capacity is composed of standard capacity and extra capacity, the provider's workload is measured by these two capacities. There are a few indicators to reflect a provider's workload (see Table 6-1)

Table 6-1: The indicators of a provider's workload

Indicator	Description
Standard capacity	The number of appointments this provider can provide within his standard session.
Extra capacity	The number of appointments this provider can provide within his extra session.
Overall capacity	Standard capacity plus the extra capacity
Standard capacity usage	The number of appointments this provider can provide within his standard session.
Extra capacity usage	The number of appointments this provider can provide within his extra session.
Overall capacity usage	Standard capacity usage plus the extra capacity usage

The indicator of a providers' workload is calculated by the following formula:

$$\text{Workload indicator} = \frac{\text{extra capacity usage}}{\text{extra capacity}}$$

The workload indicator is calculated by the extra capacity divided by the standard capacity. The reason we use this formula is to display the ratio of extra capacity usage. If the value of this indicator is 0%, it means this provider does not use his/her extra capacity at all. If this value is 100%, it means that this provider has used up all extra capacity and the workload for this provider is really at a high level.

6.2.4   Strategy module

To help with decision making for those managing the appointment system the proposed appointment system incorporates a Strategy module to store all of the

relevant rules for managing patient appointments. Due to the fact that there are no standardised guidelines advised by the Advanced Access model, the rules are collected from the literature and taken from about the practice's experience in implementing the Advanced Access model. When triggered by the signal sent from the Performance module, a relevant rule-based recommendation will be presented to the end user to assist that person to make the relevant appointment decisions.

6.2.4.1 Rules for balancing demand and supply

Currently, there are 13 rules that have been used in practice (Murray, Bodenheimer et al. 2003; Knight, Padgett et al. 2005; Meade and Brown 2006; Baugh, Alpard et al. 2008; Mehrotra, Keehl-Markowitz et al. 2008; Pomerantz, Cole et al. 2008), and which have been gathered and would be placed in our Strategy module, as listed below:

1. **Increase Provider Workload (use optional hours) (IPW(H))**: Providers provide small size extra capacity by using optional hours.

2. **Increase Provider Workload (use extra sessions) (IPW(S))**: Providers provide large size extra capacity by using extra sessions.

3. **Restrict New Patient (RNP)**: Providers refuse new patients added to their panel to reduce patients' demands.

4. **Restrict Prescheduled Appointment (RPA)**: Providers restrict prescheduled appointments on certain days for certain people to provide sufficient capacity on the specific day. This method is commonly used when practice try to shift the prescheduled appointment from certain heavy-duty days, such as the day after holiday.

5. **Deny Prescheduled Appointment (DPA)**: practice restricts the number of days that patients can make pre-booked appointments. This may reduce the number of missed appointments and improve capacity available for patient, however may sacrifice some convenience for some patients such as aged people

6. **Increase provider standard session (IPSS)**: increase a provider's standard work session, so that this provider's routine capacity will be increased, such as some of part-time providers turn to full-time during implementation of AA.

7. **Recruit a Temporary Physician (RTP)**: organisation recruits a provider to temporarily increase the health care supply. (Temporarily improve the capacity to work down backlogs or to fill the capacity gap when a provider is on holiday)

8. **Recruit a Physician (RP)**: practice recruits a provider to increase the health care supply for long term to improve long term capacity.

9. **Assign Roles to Practice Nurse (ARPN)**: practice assigns practice nurses to deal with certain cases. In this way, the provision can be increased for the long term. Nurses can be potential alternatives to improve access to diabetes care in settings where physicians are not available (Fall 2001)

10. **Group Consultation (GC)**: provider provides consultation to a group of people at the same time. In this way, this provider could improve healthcare supply.

11. **Telephone Consultation (TC)**: a patient could consult his/her GP through a telephone call. In this way, the appointment interval can be minimised; however, this rule is not applicable for Medicare claim in the Australia (Medicare Australia 2007).

12. **Shift Demand to Other Providers (SDOP)**: practice shifts patients from high workload providers to low workload providers.

13. **Appointment Redesign (AR)**: practice redesigns the appointment types and appointment intervals to increase the supply, such as evidence-based practice to decide patient follow up interval.
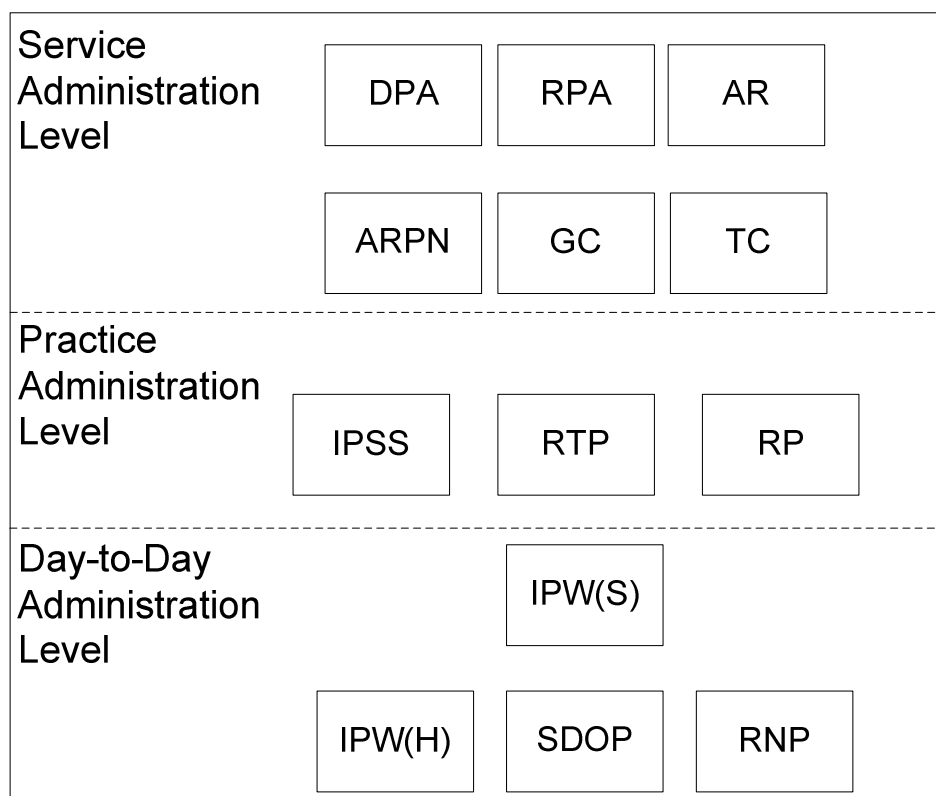
Figure 6-5: practice rules are organised in three levels: Day-to-Day Administration Level, Practice Administration Level, and Service Administration Level

These rules have then been organised at three levels based on the length of effects and complexity of implementation (see Figure 5-5): Day-to-Day Administration level, Practice Administration level, and Service Administration level. These three level rules can be invoked in different states. IPW (H), IPW (S), SDOP and RNP work at the Day-to-Day Administration level, because these rules are always used when a patient calls in to balance daily fluctuation of demands, and have short-term effects

on balancing demand and supply. IPSS, RTP and RP work at the Practice Administration level that relies on the leadership to introduce new staff member into the practice. This will result in growth of supply in the long term. Strategies at this level will be suggested to work out the backlogs for more than that which individual providers could deal with, for example in the situation when a provider has left. The rest of the rules work at the Service Administration level, because GC and TC change the way that primary health care is provided to a patient; RPA, DPA and AR decide the way to take appointment; and ARPN changes the providers' structure. All of these rules at Service Administration level will have profound effects on the provision of care.

6.2.4.2 The impact of rules on service accessibility, continuity and providers' workload

All the rules listed above either have impacts on patient accessibility, or continuity or provider's workload. Since the rules at service administration level may change the way of practice, thus it will take a longer time to adapt and have unpredictable impacts. We have listed the countable and predicable impact rules at the day-to-day administration level and the practice admission level. The purpose of these rules is to improve the provider's workload by providing optional hours, extra sessions, shifting demand to other providers, restricting new patients, improving standard sessions, recruiting a temporary physician and recruiting a physician.

1. Create extra access by increasing provider's workload (optional hour)

This rule can improve patient access by increasing provider's workload. The number of appointment a provider can provide to mitigate the fluctuating daily demand is

equals to the number of optional hours times by the number of appointments which can be provided within an hour.

$$\text{Extra Access }_{IPW(H)} = \textbf{Optional hours per day} \times \textbf{Appointments per hour}$$

If a provider can provide 1 optional hour every working day and in each hour this provider can see 5 patients, this means he could see 5 more patients every day.

2. Create extra access by increasing the provider's workload (extra session)

This rule can improve patient access by increasing the provider's workload also. The number of appointment a provider can provide to mitigate the fluctuating weekly demand equals the hours in the extra session times by the number of appointment which can be provided within an hour.

$$\text{Extra Access }_{IPW(S)} = \textbf{Hours per extra session} \times \textbf{Appointment per hour}$$

If a provider can work 8 on Saturday every working day, in each hour this provider can see 5 patients. This means this provider could see 40 more patients in a week.

3. Create extra access by shifting demand to other providers

This rule aims to improve patient access by increasing other provider's workload but reduces continuity. The number of appointment a provider can provide to mitigate the fluctuating demand relies on other provider's capacity.

$$\text{Continuity }_{SDOP} = \frac{\textbf{Offered Appointments} - \textbf{Shifted Appointments}}{\textbf{Offered Appointments}}$$

Because this rule will not affect the accessibility, the reduction of this provider's continuity equals the difference between appointments offered to this provider's own patients minus the number of shifted appointments divided by the offered appointment. This value can reflect this provider's current continuity.

4. Maintain accessibility by restrict new patients, improving standard session

This rule will not improve patient access to the practice; however, by restricting new patients' access, the accessibility for routine patients can be guaranteed. Moreover this rule will not increase provider's workload.

$$\text{Access Rate}_{RNP} = \frac{\text{Offered Appontments}}{\text{Offered Appointments} + \text{restricted Appointments}} = \frac{\text{offered appointments}}{\text{Demands}}$$

The access rate of this provider is the offered appointments divided by the offered appointments plus restricted appointments. This rate also equals to the offered appointments divided by the demand.

5. Create extra access by increasing the provider's standard session

This rule is only applicable to part-time provider because the length of their standard session is not as long as a full time provider. If this provider could work more hours routinely, his/her standard capacity is increased; meanwhile the standard workload is increased as well. As a result both accessibility and continuity will be improved.

6. Create extra access by recruiting a temporary physician

This rule can improve patient access by recruiting a temporary provider. The number of appointment a provider can provide to patients everyday equals to the daily working hours of this provider times the number of appointments this provider can provide an hour.

$$\text{Daily Access}_{RTP} = \text{Hours per working day} \times \text{Appointment per hour}$$

The overall access this provider can provides to patients equals to the daily access times by the number of days this provider works in total.

$$\text{Total Access}_{RTP} = \text{Daily Access} \times \text{Total working days}$$

If a temporary provider can work 4 hours per day, 5 days a week for 3 months and in each hour this provider can see 5 patients. This provider can provide 20 appointments per day that is 100 appointments. So totally this provider can provide 1200 appointments during the 3 month period.

7. Create extra access by recruiting a physician.

This rule can improve patient accessibility by recruit a provider. The number of appointment a provider can provide to patient everyday equals to this provider's daily working hours times by the number of appointment can be provided within an hour.

$$\text{Daily Access}_{RP} = \text{Hours per working day} \times \text{Appointment per hour}$$

If a temporary provider can work 4 hours per day, 5 days a week and in each hour this provider can see 5 patients. This provider can provide 20 appointments per day that is 100 appointments every week. Different from recruiting a temporary physician, there is no limitation of working period for this provider.

6.2.4.3 Rule Triggers

The corresponding rules will be triggered by the status of performance from three perspectives: accessibility, continuity and workload. Because rules at service administration level may change the way of the practice, it will take a longer time to adapt and have unpredictable impacts; rules at the day-to-day administration level and the practice admission level are triggered by the performance module for their countable and predicable impacts. The status of service performance and triggered rules are listed in table 6-2 (see next page):

Table 6-2: The status of service performance and triggered rules

Accessibility (Home provider)	Accessibility (Foreign provider)	Continuity	Workload (H)	Workload (F)	Rules
High	N/A	N/A	Low	N/A	N/A
Medium	N/A	N/A	Low	N/A	IPW (H)
Low	N/A	N/A	Low	N/A	IPW(H) or IPW (S)
Oversized	N/A	N/A	Low	N/A	IPW(H) and IPW (S)
Not High	High	N/A	High	Low	SDOP
Medium or Low	Medium or Low	High	High	Low	Conditioned SDOP
Medium or Low	Medium or Low	Low	High	High	Conditioned IPW(H) or IPW (S) or SDOP
Oversized (Decrease)	Not Low	N/A	High	High	IPW(H), IPW (S) and RNP
Oversized Part-Time provider (Increase)	Not Low	N/A	High	High	IPW(H), IPW (S), RNP and IPSS
Oversized Full-Time provider (Increase)	Not Low	N/A	High	High	IPW(H), IPW (S), RNP, RTP and RP

6. 3   The Design of Integrated Service Architecture

There are a few issues that have been considered in designing the architecture of the booking system. First, the design of the service architecture should be able to sustain the proposed system components and workflow for improving patient accessibility in CHC. Second, in order to make this booking system implementable, the existing IT infrastructure has to accommodate the design of the component and workflow. Last but not least, the framework should be able to support future changes. That means this architecture needs to adopt a compatible and extendable technology, which will meet the needs of change in the future.

6.3.1   The Design of System Architecture

The proposed system architecture is a three tiers design based on Web services technology. The reason for the adoption of web services is that it makes functional building-blocks accessible over standard Internet protocols and independent of platforms and programming languages. The three tiers in this case refer to the Internal System tier, the Middle tier, and the External Service tier (see Figure 6-6 next page).
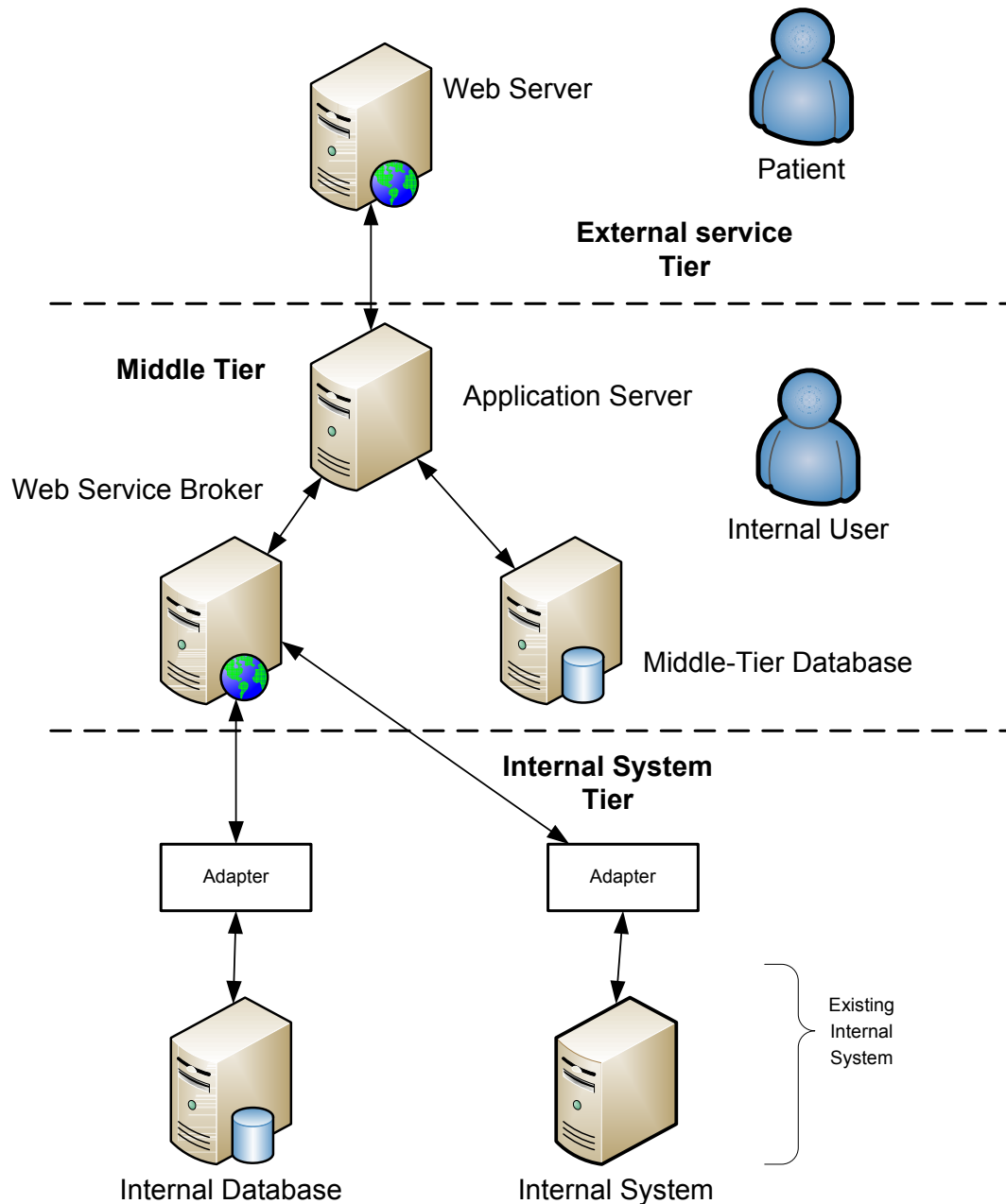
Figure 6-6: The proposed system architecture with a 3-tier design; EIS tier, Middle

tier and Presentation tier

The three-tier architectures are a better solution than one-tier or two-tier architecture

when considered as a solution for a group of clients to communicate through

different servers (Alonso 2004). The Internal System tier is composed of the existing

systems, database and adapters. The existing systems and existing database in CHC

are isolated to provide the services for a small group of users in the organisation.

These systems and databases refer to the systems and databases of PracSoft3 and Linux appointment system. These existing systems do not provide any functionality for the purpose of integration at an enterprise level. The web services adopters are the special applications that allow web services to connect to these existing systems that were not originally developed with web services in mind.

The Middle tier consists of a web service broker, an application server and a middle-tier database. The web service broker is a web service that organises the functionalities provided by different internal systems and databases into web services. An application server, on the one hand, provides the appointment application to the internal user by utilising the web services published on the web service broker; on the other hand, it provides functionalities used by the external web services, through which patients can make appointment through the Internet. The temporary data, which are used or created during the operation process, are stored in the Middle-tier database. In contrast with Internal databases that are often seen as databases of record, which are expected to last "forever", data stored in the middle-tier only need to support the process in the middle tier. All the data is eventually written to the EIS-tier database.

The only component in the external service tier is the Web Server. This is independent from the CHC internal system. In this design, this web server can be connected to the internal system through the functions provided by the application services. The online booking service can be provided to patients to relieve the pressure on the telephone booking service in CHC.

6.3.2   The Design of Web Services

There are four sets of web services designed in completing of the four modules as shown in Figure 6-1: request module, schedule module, performance module and

performance module. Each of these four services will execute a series of operations to satisfy the functionalities of each module as shown in the following sections:

6.3.2.1   The Request Module Web Service

The purpose of the request module web service is to fulfil the functionalities of recording patient request. This involves a series of operations on patients and requests. These operations are listed as follow:

- Patient Operations:

    o *GetPatientNameList*: This operation can find the related patient list by the user's input.

    o *GetPatientDetail*: This operation can retrieve a patient's detailed record.

    o CreateNewPatientRecord: This operation can create a new patient record.

    o *ModifyPatientRecord*: This operation can modify a patient record.

- Request Operations:

    o *CreateNewPatientRequest*: This operation can create new patient requests

    o *GetPatientPendingRequest*: This operation can retrieve a patient pending request.

    o *FinalisePatientRequestStatus*: After arranging an appointment, this operation can finalise the request status.

6.3.2.2   The Schedule Module Web Service

The purpose of the schedule module web service is to fulfil the functionalities of managing providers' schedule. This involves a series of operations on the provider's record, and appointment records. These operations are listed as follow:

- The Operations on Provider's Records:

    o *GetProviderList*: This operation can display a list of all providers' brief information.

o *GetProviderRecord*: This operation can retrieve a provider's detailed record.

o *CreateNewProviderRecord*: this operation can create a new provider's record

o *ModifyProviderRecord*: this operation can modify a provider's existing record.

- Operations on Appointment Record:

  o *GetAllProviderDailySchedule*: this operation can retrieve all working provider's daily schedule from the database.

  o *GetOneProviderWeeklySchedule*: this operation can retrieve one provider's weekly schedule from the database.

  o *CreateNewAppointment*: this operation can create a new appointment based on a patient's request.

  o *ConfirmAppointment*: this operation can confirm the arranged appointment

  o *ModifyAppointment*: this operation can modify the appointment data.

  o *DeleteAppointment*: this operation can delete appointment data from the providers' schedule.

6.3.2.3 The Performance Module Web Service

The purpose of performance module web service is to systemically organise the service performance, so that the user can have a clear understanding of how the service are provided to patients. This involves a series of operations on the practice performance record of CHC, including:

- Practice Performance Operations:

  o *GetOverallPerformance*: This operation will display the brief performance information.

  o *GetPracticeAccessibility*: This operation will present the performance of practice accessibility in detail.

o *GetProviderAccessibility*: This operation will present the performance of individual providers' accessibility in detail.

o *GetProviderContinuity*: This operation will present the performance of provider's continuity in detail.

o *GetProviderWorkload*: This operation will present the performance of provider's workload in detail.

6.3.2.4   The Strategy Module Web Service

The purpose of the strategy module web service is to provide recommendation to the user for balancing the demand and supply.

- Strategy Operations:

  o *GetAppointmentStrategy*: This operation will get the recommendation for arranging a specific appointment.

  o *GetPracticeRecommandation*: This operation will get the recommendation for the practice.

6. 4 Design of Appointment Booking Workflow Guided By the Proposed Appointment System

After explaining the functionalities provided by each model of the proposed appointment system, the next step is to design the workflow of this system to support Advanced Access. Two issues have to be considered in the design of the practice workflow: the first one has been to take the easiest way in utilising the AAS, and the other one is to reduce the actors involved in the booking process. Therefore, the practice activities have been put in two categories – pre-setting workflow and patient booking workflow. The proposed process of using this system to make an appointment for a patient includes three phases (see Figure 6-7).
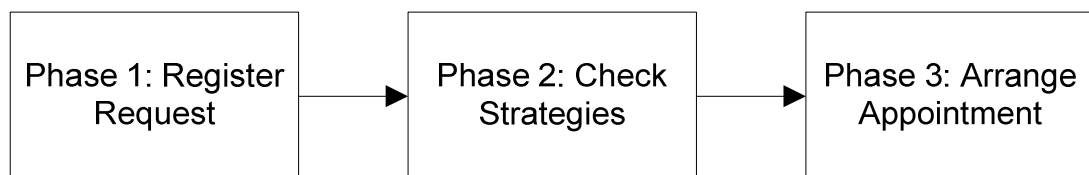
Figure 6-7: The process of arranging an appointment using advanced appointment system

6.4.1   Phase 1: Register Request

In Phase1 (In Figure 6-8), a receptionist receives a request from a patient and enters this request into the appointment system. The appointment system checks the type of request. If this request is pending one in the system, the system will pick up this pending request; otherwise, it will register a new request into the system.
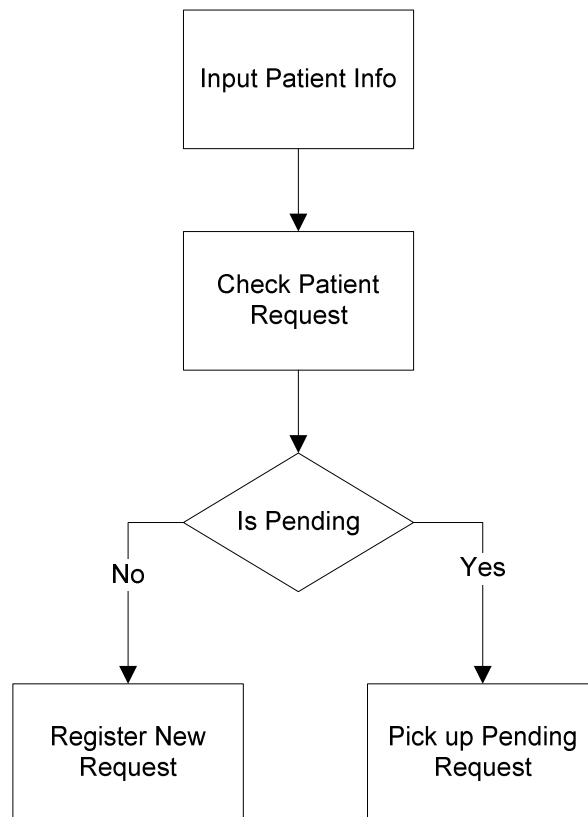
Figure 6-8 Workflow for Phase 1: Record patient request

6.4.2   Phase 2: Check Strategies

After registering the patient's request, the appointment system checks the performance of this type of service. The performance is measured by three attributes: accessibility, continuity and workload. If the system performance remains at the acceptable level, the system will execute according to the default strategy. If the Performance module identifies abnormal performance, it will trigger a corresponding

alarm in accordance with the relevant rules in its rules database, which is managed by the Strategy module. This will alert the end user to implement the relevant strategy to improve the service performance (see Figure 6-9).
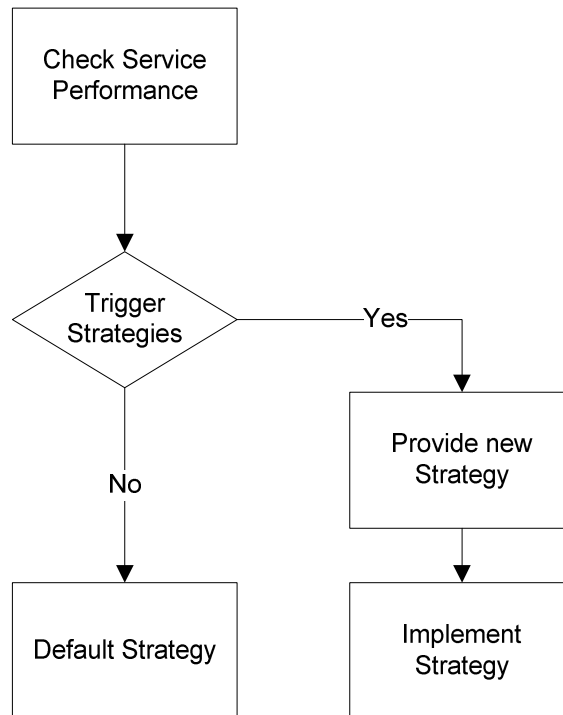
Figure 6-9 Workflow for Phase 2: Check Strategies

As mentioned in Section 6.2.4, we have identified 13 rules that may affect the provision of care for a patient from short term to long term. If the declination of service performance has been identified by the system, it will provide suitable rules to the user for rebalancing the demand and supply according to Table 6-2.

6.4.3 Phase 3: Arrange Appointment

In Phase3 (see Figure 6-10), the receptionist follows the selected rules to arrange an appointment for the patient. If the patient is satisfied with the appointment, then the patient's demand has been fulfilled and the request changes to a booked appointment. If for any other reason that the appointment is not booked, the system will postpone this request, and this request becomes a pending request.
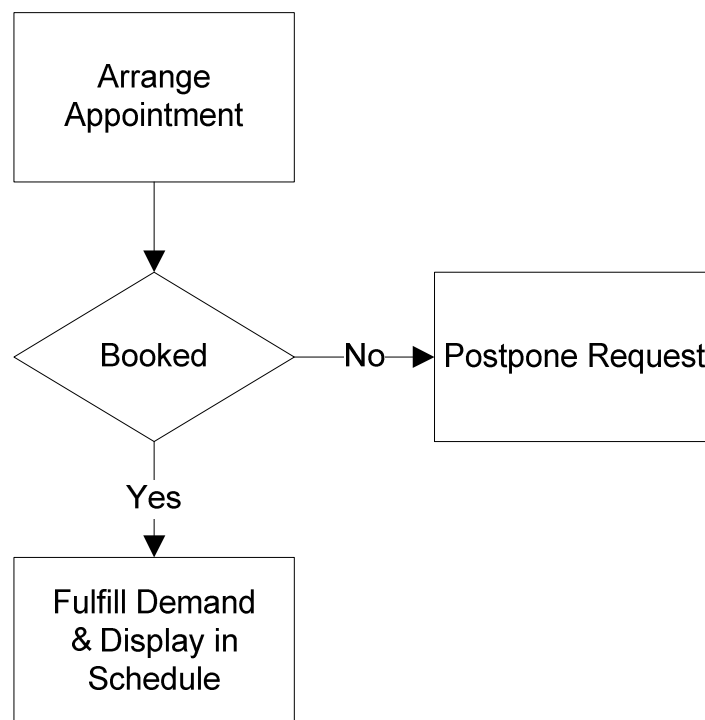
Figure 6-10 Workflow for Phase 3: Arrange Appointment

6.4.4   The Overview of Booking Workflow

The following activity diagram of the workflow in using the new appointment system is drawn as an overview of the workflow described in this section. The major changes can be described from three points: (1) patients are not sorted into two categories as before; (2) practice manager's activities and doctors activities have been dissociated from patient's booking process; and (3) the data entry point has been put at the very beginning of the booking process. All these changes are dedicated to improving the patient's access from different perspectives.
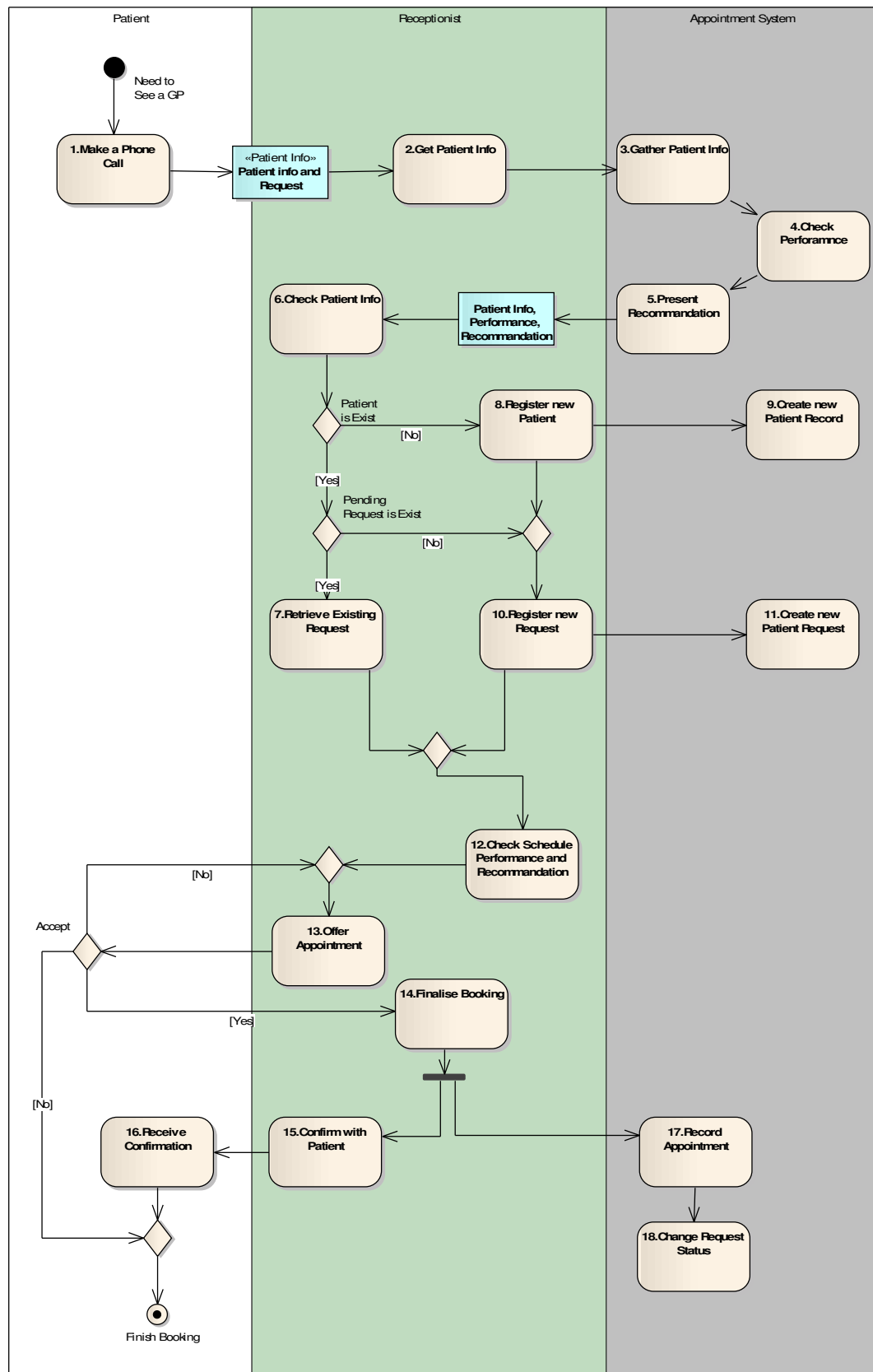
Figure 6-11: Detailed design of appointment booking workflow

This workflow (in Figure 6-11) starts when a patient makes a phone call and passes their personal information and appointment request to the receptionist (Activity 1). The receptionist receives the information and inputs the patient's name through the appointment system's interface and requests for the patient's information from the appointment system (Activity 2). The appointment system first gathers the patient's personal record and find out the pending request from the database (Activity 3). Then the appointment system checks the performance of the patient's family provider and other providers (Activity 4). Finally the appointment system provides recommendations for arranging an appointment for this patient (Activity 5). The appointment system sends the patient information, performance information, as well as the recommendation to the system interface, and the receptionist then needs to check the patient information (Activity 6).

If the patient's record indicates that this patient is a previous patient of the practice, and there is an un-arranged pending request for this patient, the receptionist would retrieve this patient's pending request (Activity 7). If the patient is a previous patient of the practice, but there is no pending request for this patient, the receptionist will register a new request for this patient (Activity 10). If the patient is new to this practice, the receptionist will first register a new patient in the system (Activity 8), and the appointment system will create a new patient record in the database (Activity 9). Afterwards, the receptionist needs to register a new request for this patient (Activity 10), and the appointment system will store this request into the database (Activity 11).

After checking the patient's information, the receptionist accesses the practice performance including the patient's family doctor's performance and that of other doctors and the recommendation from the appointment system (Activity 12). The

receptionist then offers an appointment to this patient (Activity 13). If this appointment is accepted by the patient, the receptionist will finalise the booking process (Activity 14). This new appointment needs to be stored in the database and the request status is changed to "booked".

6. 5   Design of System Interaction

In this section, the sequence diagram was used to show the messages exchanged between actors and system components to fulfil a routine booking process. These components include the new appointment system interface, web services, and appointment databases, as well as the databases used by legacy systems. Four sequence diagrams were selected to represent this process as: starting up; retrieving patient's details, recording patient's request and arranging an appointment.

6.5.1   System Interaction for Starting up

The start-up activity is the system's internal interactions. It starts with receptionist requesting to the opening of the booking page, and the page pops up on the system interface. The messages are exchanged among one actor and four system components (in figure 5-12) as: (1) receptionist; (2) system interface; (3) web services; (4) appointment database; and (5) existing database.

At the beginning, the receptionist clicks the link to the booking page. In order to provide the booking page, the system interface needs to gather three pieces of information. This information includes: (1) provider's schedule; (2) general information on practice performance; and (3) the recommendation for the practice. Therefore, the system interface calls the method provided by the corresponding web services: schedule web service, performance web service and the strategy web services. To get the provider's schedule information, the schedule web service call the method to retrieve the providers' index information stored in the appointment database, and then collects the schedule information from existing database used by family providers and AHPs according to the message stored in the index, which indicates the location of providers' schedule data. To get the practice performance data, the performance web services calls the method to retrieve demand related data from the appointment database, and organise these data as practice briefings. To get the practice recommendation, the strategy web services calls the method to retrieve practice performance data from the appointment database and generates the recommendation based on the practice performance. After these three pieces of information are prepared, the system interface displays the booking page to the receptionist.
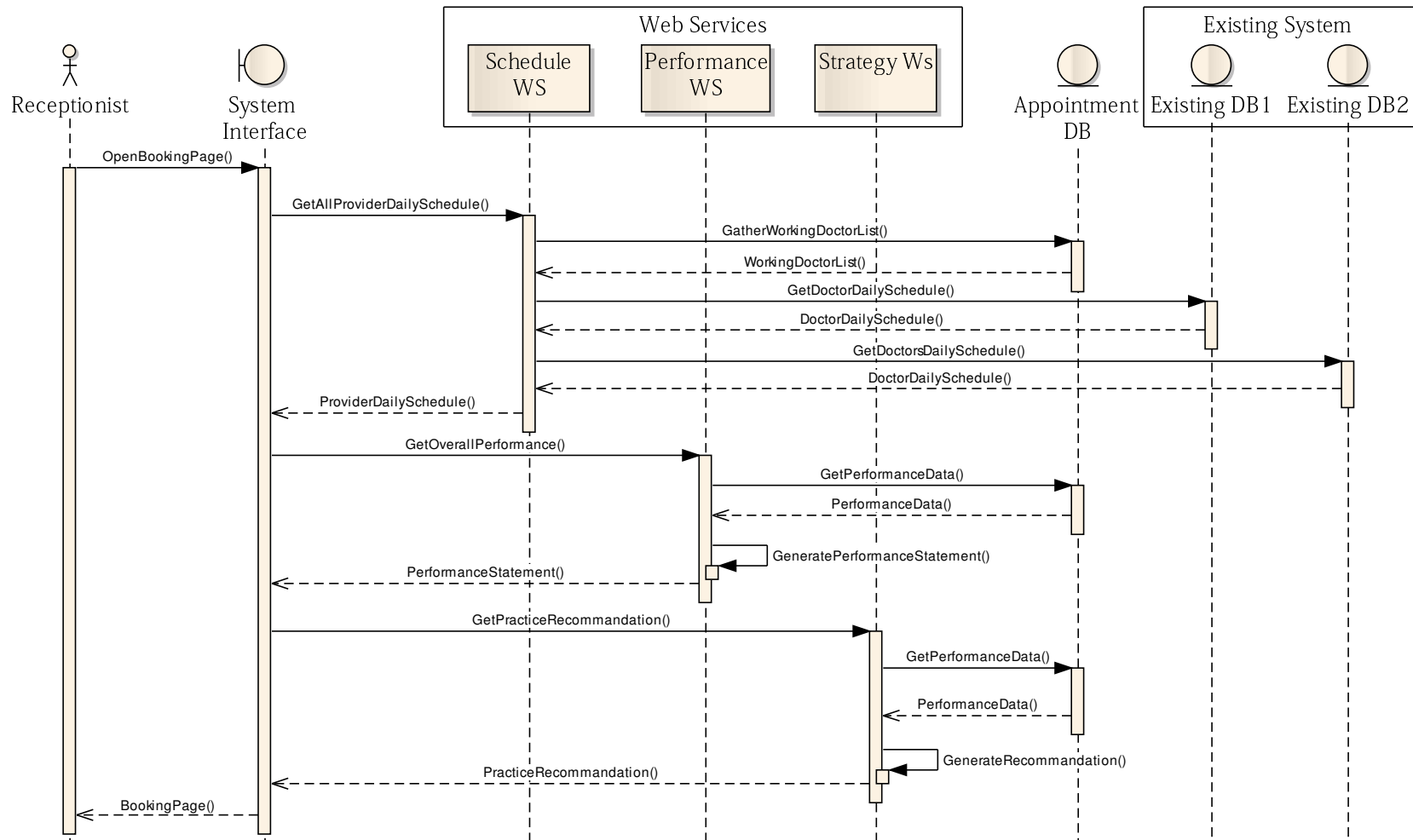
Figure 6-12 Sequence Diagram: Starting the booking page

6.5.2   System Interaction for Retrieving Patient's Detail

The process of retrieving patient's details is undertaken by the internal interactions between the appointment system and the receptionist. These include receiving patient's request and popping up the patient details through the interface. The messages are exchanged through two actors and three system components (see figure 6-13) as: (1) patient; (2) receptionist; (3) system interface; (4) web services; and (5) appointment database.

At the beginning, the patient passes the message to the receptionist. This message contains the patient's personal information and the request for an appointment. In this process, the receptionist just needs to check if the patient's record exists in the appointment database and whether there is a pending request for this patient. So receptionist enters the patient's name in the patient search engine on the system interface. The system interface calls the method of *GetPaitnetNameList()* that requests web service to retrieve a list of patient names that are close to the patient's input. The request web service then calls the method to get the related patient from the appointment database.

After browsing the patient's list, the receptionist selects the name of the patient who initiated the request. The system interface then calls two methods provided by the request web services (1) *GetPatientDetail*() and *GetPatientPendingRequest*() to retrieve the selected patient's detailed information and pending request from the database. Retrieving the request, the request web service calls the corresponding method to retrieve the corresponding data from the appointment database.
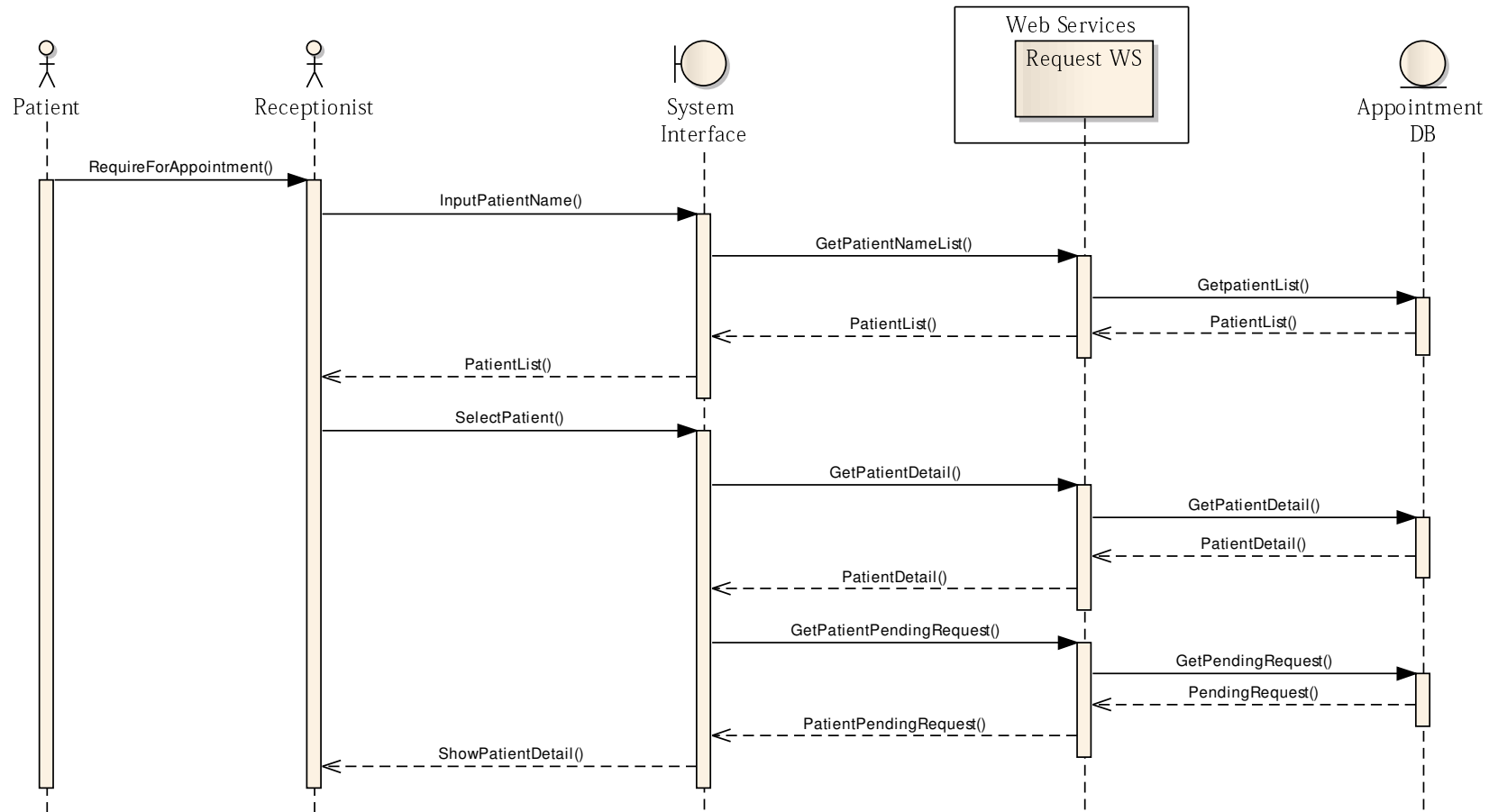
Figure 6-13 Sequence Diagram: Retrieving a patient's detail

6.5.3   System Interaction for Recording Patient's Request

The recording patient's request process is the internal interaction between the system and the receptionist, starting from receptionist creating a new request to system interface popping up the request. The messages are exchanged through one actor and four system components (in figure 6-14): (1) receptionist; (2) system interface; (3) web services; (4) middle database; and (5) appointment database.

At the beginning, the receptionist needs to create a new request on the system interface. The system interface calls the method provided by the request web service to create a new request in the middle database. The middle database, as was mentioned in Section 6.3.1, is used to store temporary data that are created during the appointment booking process. Then the interface calls the methods provided by performance web service to retrieve detailed performance information for the patient's family doctor. These details include the doctor's accessibility, continuity and workload. After receiving the performance data, the system interface updates the information section, which is used to display practice performance. Meanwhile, the system interface calls the method provided by the strategy web service to get the recommendation for arranging an appointment matching the patient's request. In the end, the system interface displays an updated page to the receptionist, which contains the patient's request, the patient's family doctor's performance and the recommendation for a future appointment if it is needed.
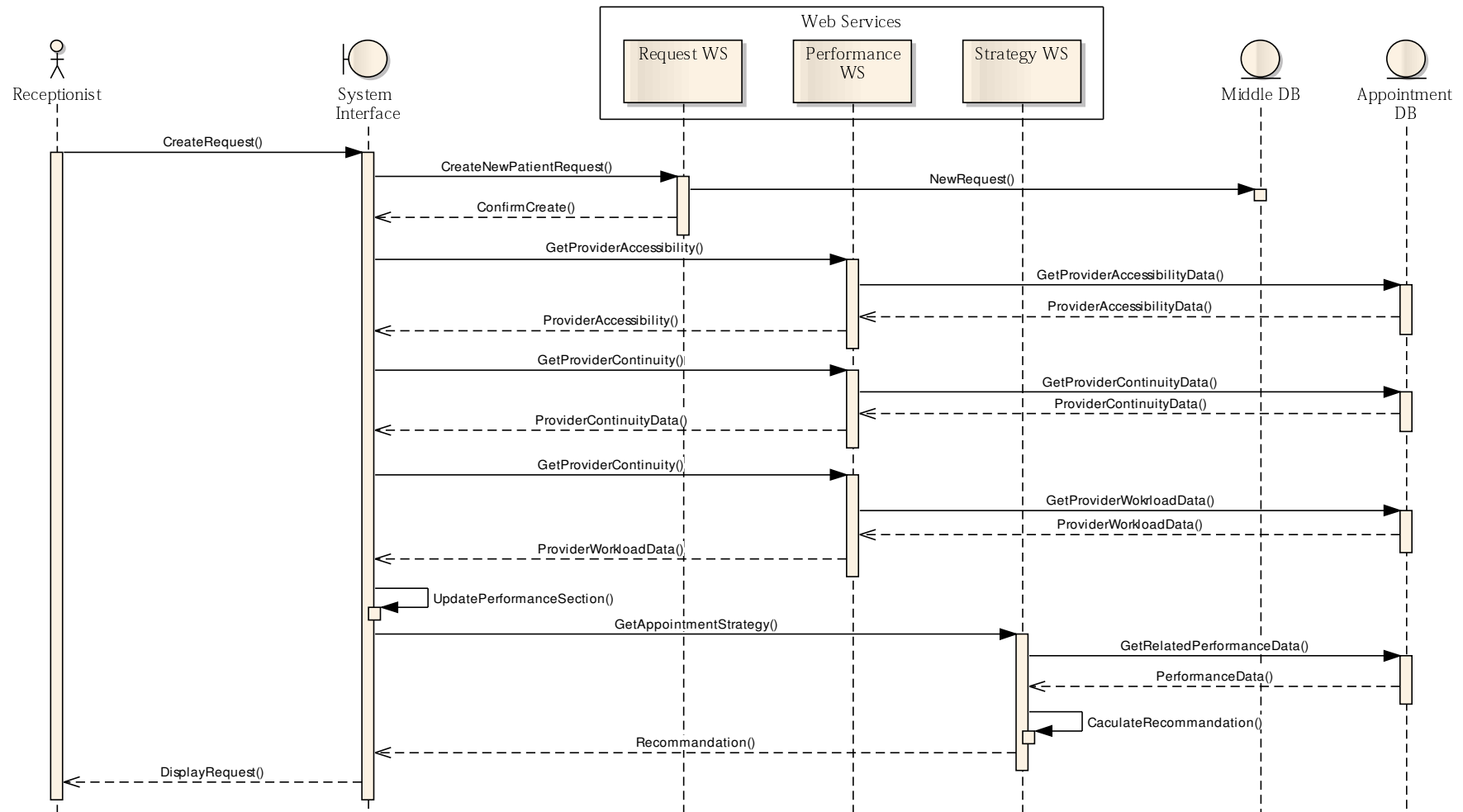
Figure 6-14 Sequence Diagram: Recording a patient's request

6.5.4   System Interaction for Arranging an Appointment

The arranging an appointment process is the internal interactions between the system and the receptionist, starting from the receptionist creating a new request into the appointment system to arranging an appointment for the patient. The messages are exchanged through one actor and five system components (in figure 6-15) as: (1) receptionist; (2) system interface; (3) web services; (4) appointment database; (5) middle database; and (6) existing database.

After assessing the providers' performance and recommendation, a consensus about the appointment time and doctor should be reached between receptionist and patient should be reached. So the receptionist operates on the interface to arrange an appointment for the patient. The system then calls the method provided by the schedule web service to create a new appointment. The schedule web service creates a new appointment record in the middle database. After the receptionist confirms the creation of the appointment, the system interface would call the method provided by the schedule web service to confirm the creation of an appointment. The schedule web service would retrieve the temporary appointment data from the middle database and restore this data into the appointment database and the legacy databases. Meanwhile, the system interface would call the method provided by the request module to finalise the request. The purpose of finalising the request has been described in 6.4.3 as an activity to modify the request status. Not only modifying the request status, the web service also retrieves the request from the middle database and stores it into the appointment database.
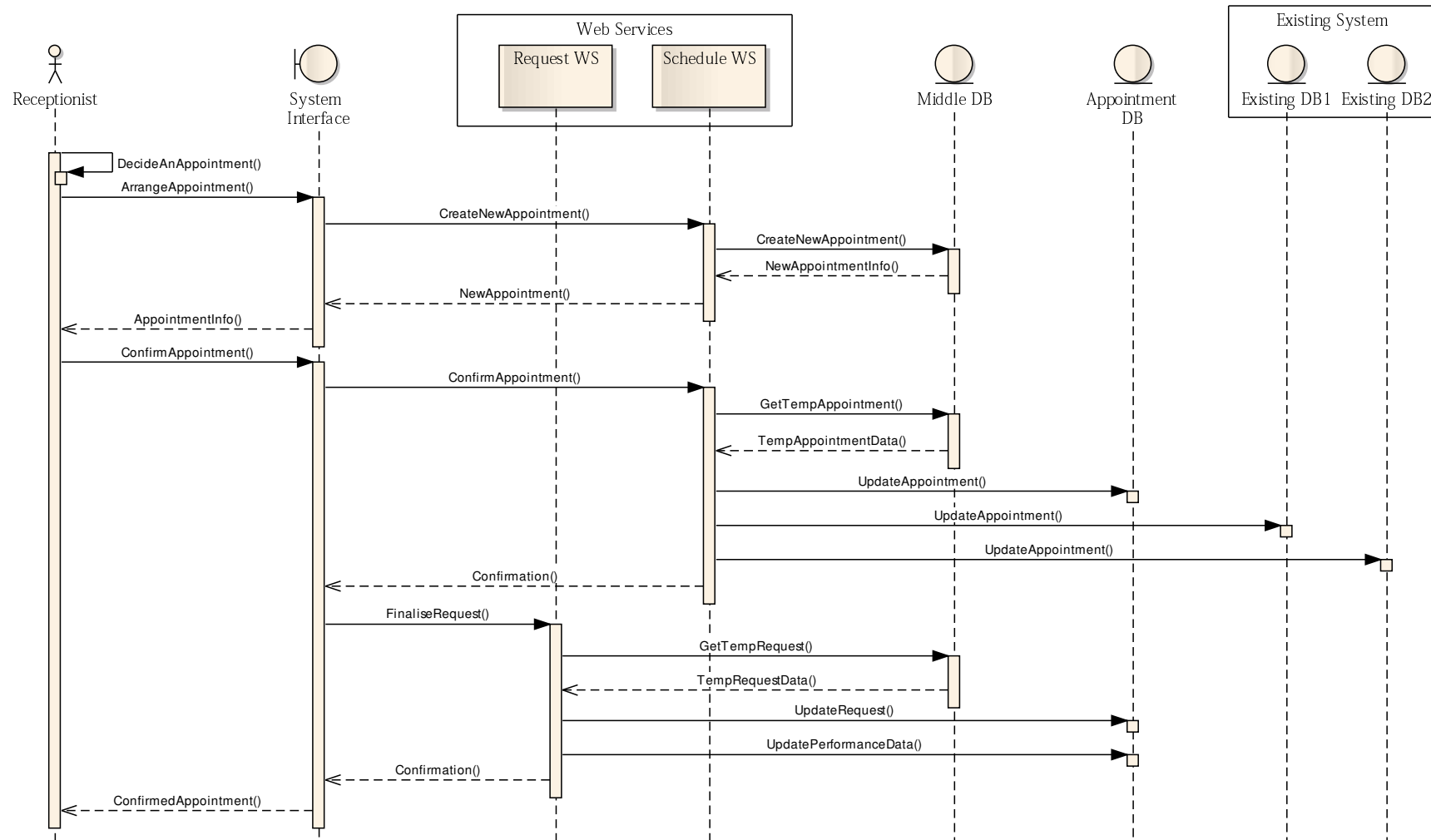
Figure 6-15 Sequence Diagram: Arranging an appointment to a patient

6. 6 Summary

This chapter presents the design for the Advanced Appointment System from four perspectives: modules, web services, operation workflow, and system interaction. This system consists of four modules: the request module, the schedule module, the performance module, and the strategy module. These modules interact to dynamically managing the practice performance, which is measured by accessibility, continuity and the provider's workload. The web service based architecture is introduced to integrate the isolated system environment. As the proposed appointment system provides an innovative design, which is discrepant with the existing appointment system, the design of the practice workflow is to support its implementation. Finally, the detailed interaction diagrams are used to describe the operations between system components.

7. PROTOTYPING AND UNIT TESTING

7. 1   Introduction

The prototype is a basic implementation of the system design. It builds the possible solutions for the system design as presented in the Chapter 6. The implemented functionality in the prototype is limited to the scope of this thesis. It does not represent a full featured appointment system. The development of the prototype has been concentrated on a few features, which are able to show the integrated appointment infrastructure, the use of web services technology and database, as well as unit test methods. Section 7.2 presents the architecture of the .NET 3.5 programming based on the windows platform. Section 7.3 presents the prototype of the component design. Section 7.4 covers database prototype and Section 7.5 discusses the implementation of online booking components. This chapter concludes with a summary.

7. 2   Windows Programming Architecture

The prototype is primarily a .NET Framework 3.5 based web services application that runs on the Microsoft Windows Server 2003 (see Figure 7-1). The Common Language Runtime (CLR) is the environment in which .NET components exist and execute (Scribner and Stiver 2001). On top of CLR is the base class library (BCL), which is a standard library available to all languages using the .NET Framework including XML, ADO.NET etc. web services run on the ASP.NET platform based on the BCL.

Appointment System

Web Services

Base Class Library

Common Language Runtime (CLR)

Operating System
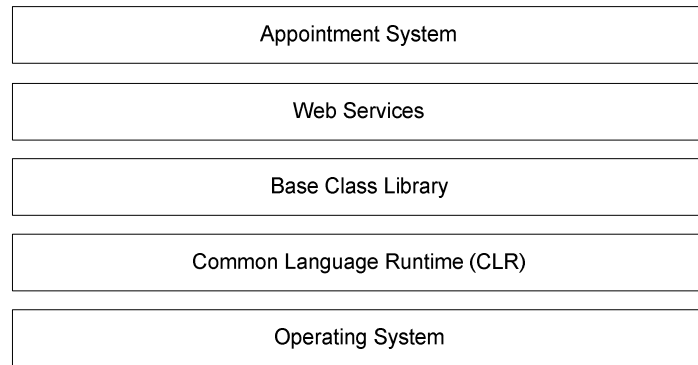
Figure 7-1: The architecture of the prototype system

There are many important libraries we have used in building the prototype of the appointment system, such as: (1) System.Linq, (2) System.Web.Services and (3) AAS_Library.

The System.Linq, which supports queries that use Language-Integrated Query (LINQ) (MSDN 2010), provides a convenient method for executing language-integrated queries into SQL for execution by the database, and then translating the tabular results back into objects you define; System.Web.Services enables the XML Web services using ASP.NET and XML Web service clients (MSDN 2010); and AAS_Library, which was create in this project, consists of the classes that facilitate the functions provided by the prototype web services.

7. 3   Components

In Chapter 6, the four component modules have been proposed: requests recording, provider's schedule management, performance monitoring, and appointment strategy provision. All of these modules have been built as web services in Section 6.3.2. In this section, Section 7.3.1 presents the prototype of web services design. Section 7.3.2 discusses the unit testing technique used in the programming process to validate the correctness of the codes.

7.3.1 Web Services

There are four web services listed in Section 6.3.2 for the purpose of request, schedule, performance and strategy management. In each web service, there are many operations that can be used by the user to exchange specific data during the booking process. In ASP .NET programming, these operations will be collected in a web file with an .asmx extension, which stands for web service page.

Please see print copy for image

Figure 7-2: Web service page of request web service, on which operations are listed

For example, on the request web service page (see Figure 7-2), prototype operations are listed. Functionalities of these operations are consistent with the definition described in Section 6.3.2. By clicking the link for service description, the page would turn to the WSDL file to describe this service. This file is used to determine

what operations are available on the server, and special data types and occurrence used in the form of XML Schema.

7.3.1.1 Operation

The operation *GetPatientList* is used to get patients' names in the database that is most similar to the user's input. This will enable the user to retrieve the patient's name as quickly as possible. When clicking the link of *GetPatientList*, it shows the operation page (see Figure 7-3).
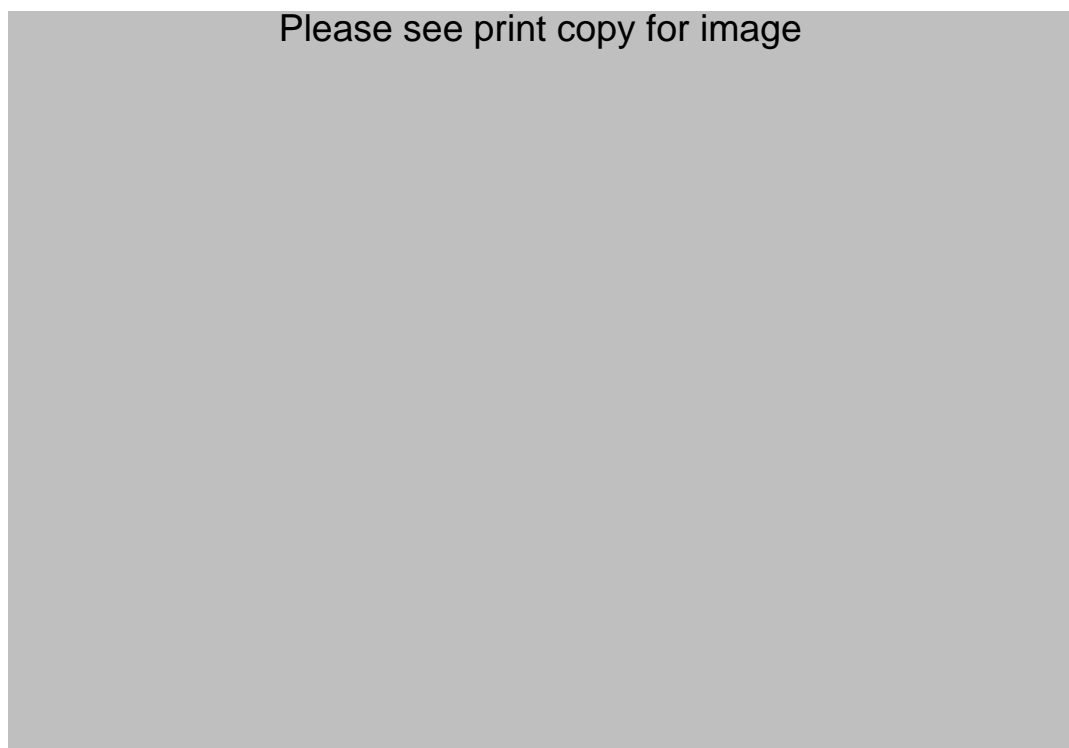
Figure 7-3: Two sections on operation page of *GetPatientList*

There are two sections on the *GetPatientList* operation page. The Section on the top is used to test the correctness of this operation, and the Section on the bottom are the SOAP files, which use Internet application layer protocol as a transport protocol to pass objects between server and clients.

7.3.1.2   SOAP

The SOAP version 1.2 file for the *GetPatientList* operation is displayed in Figure 7-4.

In the first soap file, two variables are defined in the body text to send to the server:

prefixText and *count*. *prefixText* is a string type variable, which is used to record the

first few letter of the patient's name input by the user. *Count* is an *int* type variable,

which is used to decide the number of related patient's name to be displayed on the

page. In the second soap file, the response text is a list of *string* type parameters to

show the full patient's name, which is related to the previous user's input.

Please see print copy for image
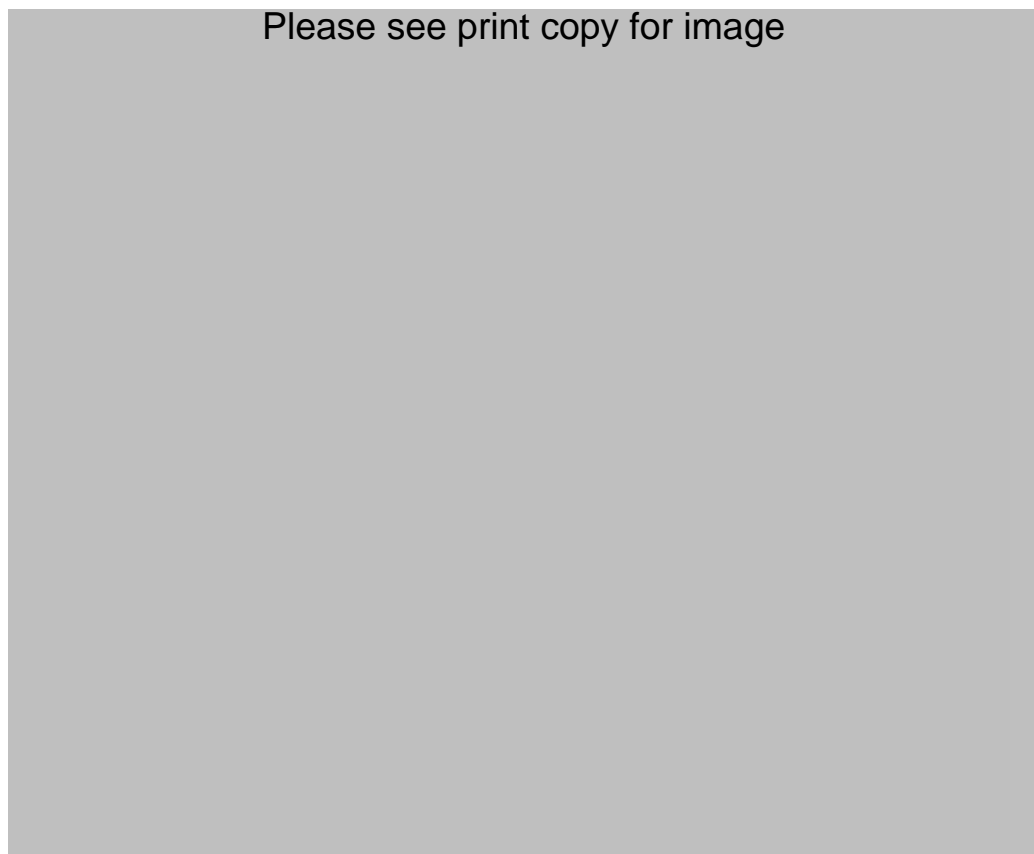
Figure 7-4: SOAP version 1.2 file for GetPatientList Operation

7.3.1.3   Test Operation

As mentioned in Section 7.3.1.1, the test function was method was provided on the

operation page. This method can be used to test the web service operation with

primitive type inputs. The primitive type refers the basic type is a data type provided

by a programming language such as: integer, Boolean, float, character etc. In this case, both the *prefixText* and *count* are primitive type variables. The process to test the operation is listed below.

Figure 7-5: *GetPatientList* Test with two inputs

In the *GetPatientList* operation page (see Figure 7-5), the *prefixTest* was given a value of 'J', which meant the patient's name started with the letter J. The count is given a value of '5', which means that there has been a maximum of 5 patients' names listed on the result page. After clicking the 'invoke' button, the result is calculated by the system and showed in figure 7-6. The above information suggests that there are five people's names listed in the sample database, whose first name started with letter 'J'.
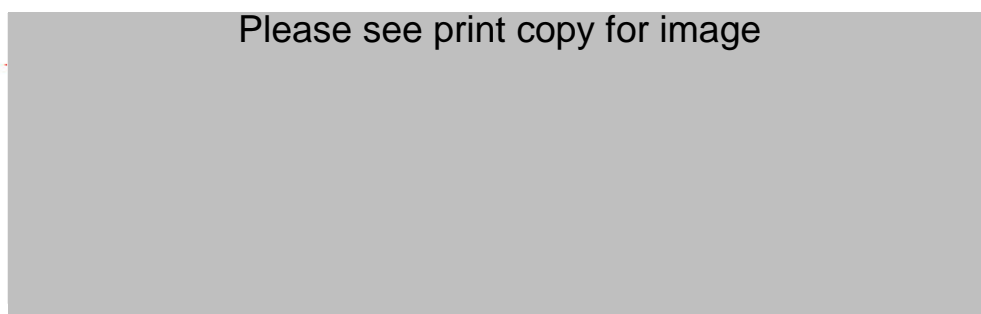
Figure 7-6: Test result of *GetPatientList* operation

7.3.2   Unit Testing

For the operations with primitive type inputs, the test method provided on the operation page is sufficient to test the correctness of the code. However, there are still some operations with composite inputs, including structures, classes, arrays, for which test methods are not provided. Thus we use the unit testing method to test the correctness of source code. For example, for the *CreateNewAppointment* operation in schedule web service, the input was a custom type of *ApptInfo*, and there was no operation test provided on the operation page (see Figure 7-8).

ScheduleWebService

Click here for a complete list of operations.

CreateNewAppointment

Test

The test form is only available for methods with primitive types as parameters.

SOAP 1.1

The following is a sample SOAP 1.1 request and response. The **placeholders** shown need t

Please see print copy for image

Figure 7-7: The test operation is not available if the input parameters are not a

primitive type.

Therefore, the unit test is added to the internal method *CreateNewAppointment* provided by *ScheduleOperation* class. In the unit test code (see Figure 7-9), we set up three values: an input value passed by the method *CreateNewAppointment*, an expected and an actual result after execution. Break points are also set up in the program so that the value of every parameter used in the program can be monitored.

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Figure 7-8: Unit test code for *CreateNewAppointment*

7. 4 Prototype Database

The database to support the prototype program was designed (see Figure 7-9). There were 11 tables in this database. Five of which were core tables for appointment recording and the rest were used to record supportive data.
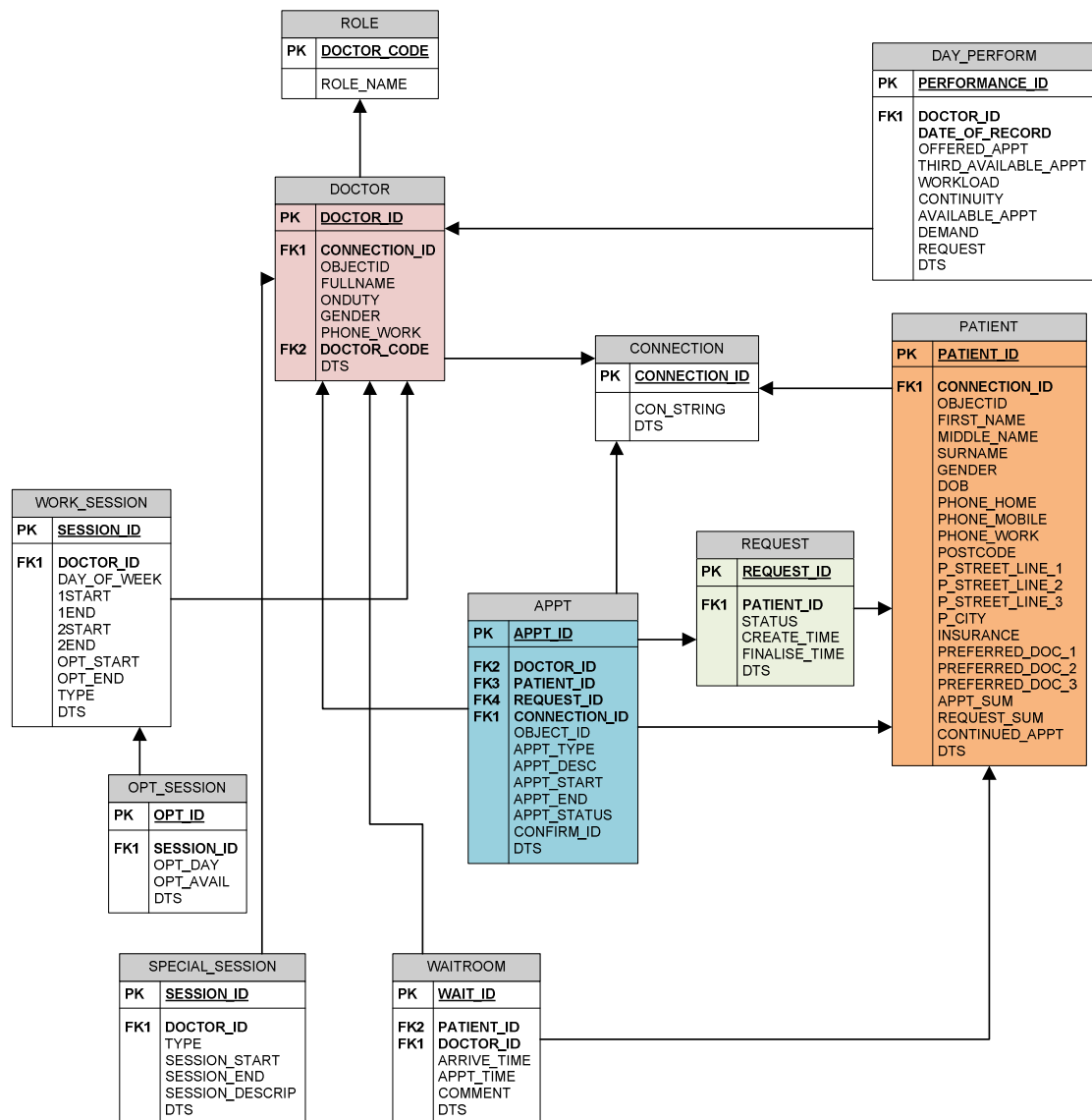
Figure 7-9: Database to support the prototype program

The usage of each table is listed below in table 7-1:

Table 7-1: Usage of each table in the middle database

Table Type	Table Name	Usage
Core Tables	DOCTOR	Is used to record doctor related metadata
	PATIENT	Is used to record patient related metadata
	REQUEST	Is used to record patients' request and the status of each request
	APPT	Is used to record appointment related metadata, including patient, doctor, request, date and time.
	DAY_PEROFRM	Is used to record daily performance for each doctor and the whole practice
Supportive Tables	WORK_SESSION	Is used to record every doctor's standard working hours and optional hours in a week
	OPT_SESSION	Is used to record the availability of every doctor's optional working hour on a specific day
	SPECIAL_SESSION	Is used to record the day of absence or extra work session based on the standard work session
	ROLE	Is used to record the doctors' different specialty
	WAITROOM	Is used to record the patient' information when a patient arrive at the medical centre
	CONNECTION	Is used to record the location and connect string of existing database

7. 5 Infrastructure

The prototype appointment system was finally placed in the real environment for future testing and improvement (see Figure 7-10). As was mentioned in Section 4.5.3, the existing appointment systems used by GPs and AHPs were implemented in the Windows server CHA-Brain and the Linux server respectively. The prototype appointment system was placed in a spare Windows server named CHA-STEM. The external web server could get through to the service published on CHA-STEM.
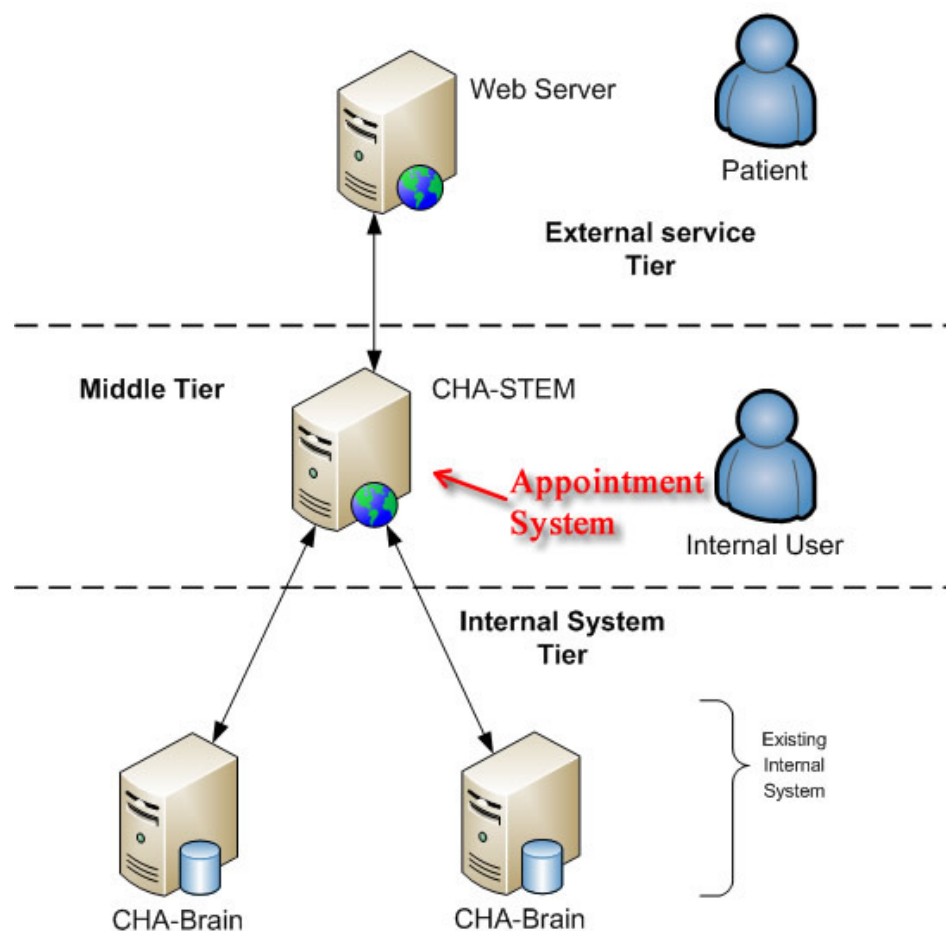
Figure 7-10 Infrastructure of the prototype appointment system

The four Web services and the database of the prototype system were implemented in the CHA-STEM. The prototype of the online patients' service has been placed on

the external web server for test purposes. The system adapter, which was mentioned in Section 6.3.1, was coded in the form of store procedure, so that the appointment system would not overwrite the existing database directly. Due to the limitation of time, the system interface was not finished by the time of thesis writing.

7. 6   Summary

This chapter discussed the results of research Phase3: prototyping and unit testing. At the beginning of this chapter, the prototype of the appointment system components was described, including web services programming and unit testing. Web service was discussed from three perspectives: the operation, SOAP and operation test. Unit testing in this project as a supportive method to test the correctness of the web service operations with composite inputs. Finally, the prototype of the middle-tier database was briefly described. This chapter concludes with a description of the implementation of the prototype program.

8. CONCLUSIONS AND RECOMMENDATIONS

8. 1 Summary

The objective of this research was to design an automated appointment system that (1) integrate the existing appointment systems used by General Practitioners (GPs) and Allied Health Professionals (AHPs), (2) provide effective response to patient requests to access GP and allied health services in a primary health care centre in Australia. The problems associated with appointment booking process for both patients and the practice were investigated through observational study and mining the booking records in the existing appointment system.

At the start of this research, the characteristics of the traditional appointment model for primary health care services were evaluated. Murray (2003) defines this model as an appointment booking process of occupying a doctor's available appointment slot with a patient's request. If the doctor's schedule is fully booked on a certain day, this patient would be given a time slot in the next available time. This model is fully based on the availability of services of providers. Its advantage lies with its simplicity in implementation and operation.

However, this model has a fundamental drawback in meeting the demand of patients for primary care services because it does not consider how many patients request services on a daily basis. Consequently, there is no evidence available for the providers to plan the services to fully meet patient needs. As a result the provider's backlog is formed. Ultimately, this backlog will lead to a consistent delay of services to patients.

There are two appointment systems used in CHC, one for allied health services, one for GP services. They both follow the traditional appointment model. The

appointment system used by GPs is a minor computer application bundled with an electronic medical record (EMR) used by every GP in the practice. This appointment system can retrieve and update patient information from the EMR, but it still does not record the number of patient request for services; therefore, it entails the same drawback of the traditional appointment model. The other appointment system used by allied health professionals is a basic web-based application, which can only record some preliminary patient information. The recorded data is not linked to any EMR because the AHP use paper-based records; therefore, it also has the same limitation as the traditional appointment model.

The workflow associated with making appointments for patients in CHC was also investigated. This workflow is generally the same for both GPs and AHPs. It can be described as a process by which a patient's request is placed into a doctor's available time slot in the computer-based appointment system. Actors in this process include patients, receptionists, practice managers, doctors and the appointment system. Every activity involved in making a patient appointment was recorded. These activities were presented in the form of UML diagrams (see Page 51 Figure 4-4 to 4-7). The IT infrastructure in the clinic, including workstations, servers, network and applications, were analysed in order to better understand the operational environment in the clinic.

In an effort to find an alternative approach to manage patient appointments, a literature review of existing appointment models was carried out. The result suggests that the Advanced Access model provides is the best basis for a solution. This model aims to match the supply with demand, diminishing the backlog of appointments and the delay of primary health care services by promptly offering patients with the requested services. The author of this model proposed several steps to achieve that goal, including balancing demand and supply, working down the backlog, reducing

the appointment types and providing contingency plan. However, to implement this model in the practice would take much effort on recording patient requests, adjusting provision strategies in regard to patient demand and providers' workload.

The new appointment system was based on the existing computerised appointment system in the CHC to reduce unnecessary changes to the current workflow. A systemic system development approach, which followed the Software Development Life Cycle, was employed in designing the new appointment system. This approach includes three research phases: (1) Requirement analysis, (2) System design, and (3) Prototyping and unit testing. Steps followed include identifying the inefficient component of the current appointment system, proposing new architecture for appointment system, identifying the inappropriate activities and modify them in order to reduce patient booking delays, and finally integrate the components used by different providers.

The new appointment system was designed in a four-module based scheme to comply with the Advanced Access model (Section 6.2). These four models include (1) a request module to manage patient requests; (2) a schedule module to manage providers' service supply; a (3) performance module to constantly monitor the status associated with appointment booking, such as the percentage of fulfilled requests, the time to "the third next available appointment" and providers' workload; and (4) a strategy module to provide recommendations for taking appointments.

The Web service technology was selected to build the integrated infrastructure in the clinic (Section 6.3). Web service was chosen because of its capacity of integrating complex hardware and software environment together. Scalability is required to accommodate the potential future integration of services of regional health care providers. The booking workflow was restructured in order to comply with the new

appointment system (Section 6.4). This workflow includes three phases: registering a patient request, selecting suitable booking strategies and offering an appointment to the patient. It is anticipated that the justified workflow could help the clinic users in utilising the new appointment system more effectively.

In summary, this research has achieved the two primary objectives in designing the new appointment system for CHC. By using a Web service based architecture, the new design has enabled the new booking system to integrate with the two legacy appointment systems used by administrative staff, GPs and AHPs by providing Web services based infrastructure. A four-module-scheme in its design would enable the booking system to record every patient request by the request module effectively. The other modules are devoted to process the request according to the defined protocols to maintain efficient access. Even though the evaluation of the design was not conducted in this research due to the limitations of time, resources, and lack of administrative approval by the management of CHC, the Advanced Access model has been proved successful in improving patient access. Our design is based on this model, as it is clear that a system based on this design will improve patient's access in CHC.

8. 2   Key Achievements

This one and a half years research project has started with understanding patient appointment processes in primary health care. Based on the knowledge acquired from one clinic, an innovative prototype appointment system was designed in an effort to overcome the shortcomings of the patient appointment process in this primary healthcare clinic. There are three key contributions of this project to the scientific body of knowledge:

- Understanding the workflow of patient appointment booking process in the Australian primary health care as represented by Centre Health Complex and presenting the knowledge in UML diagrams.

- Identifying the weak points within the existing appointment workflow with risks of hampering patients' timely access to primary health care services. This knowledge provides evidence to support the view of the Advanced Access model instead of the traditional appointment model.

- Designing an innovative appointment system that could help the practice to provide better accessibility to its patients. This appointment system adapts the idea of the Advanced Access model and is based on web service technology. This appointment system can be easily accessed over the CHC's intranet and the Internet, and executed on a remote system regardless of the operating system in use. In such a way, the new appointment system could help the practice to integrate the appointment data from the existing legacy systems, across different health care providers.

8. 3   Limitations

As a research project focused on system design, the major limitation of this research has been the short time, resources, and lack of administrative approval by the management to implement the appointment system in the clinic. Because this is a Masters Degree research project with duration one and a half years, time is not adequate for implementing and evaluating the performance of prototype appointment system in the practice, nor for testing its compliance with the requirements. The design of the prototype system was based on the requirements captured from Centre Health Complex. Therefore, the designed system may not be fully applicable to other practices or specific health care provider. Despite these limitations, we believe that our attempt in applying rule-based strategy to balance patients' demand and health service supply is an innovative approach that is useful for improving the quality of

primary health care services as measured by accessibility, continuity and the provider's workload.

8. 4 Future Work

The following work has been planned to advance this research topic:

8.4.1 System Implementation and Evaluation

It is recommended that the prototype appointment system be fully implemented in the Centre Health Complex, including the system design detailed in Chapter 6. By doing so, the current difficulties in the patient appointment process in CHC can be overcome.

8.4.2 Rule Mapping

In our proposed prototype system, the module of service performance monitoring was the fundamental component to evaluate the efficiency of appointment services in a clinic. The rule-based strategy needs to be implemented to evaluate its impact on the appointment practices. Currently, the high level rules have not been mapped to the three characteristics of performance. It is recommend that data models for mapping high level rules be studied in the future in order to support the system performance in terms of: accessibility, continuity and the provider's workload. This work need to be completed in the future project.

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