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Fault Tolerance in Intranet Information Systems for Tertiary Health Institutions

Oladejo Sunday O.[1*] Adeosun O. O.[2]

1. School of Science and Technology, National Open University, Osogbo Study Centre, 14/16 Ahmadu Bello Way, Victoria Island, Lagos, Nigeria
2. Department of Computer Science and Engineering, Ladoke Akintola University of Technology, P. M. B. 4000, Ogbomoso, Oyo State, Nigeria.

* E-mail of the corresponding author: osoladejo@camagtech.com

Abstract

The critical nature of information and data in some systems like health sector requires a system that gives optimal tolerance to fault without trading off or compromising system integrity, availability and security in order for the system to afford greater efficiency. The main thrust of this work is to examine health system information flow and application(s) in the light of fault tolerance and come up with application software of higher tolerance to fault that can be deployed as an intranet in a tertiary health institution for sharing Patients' Case Notes among care givers. Besides extensive literature review on the work, Ladoke Akintola University of Technology Teaching Hospital, one of the teaching hospitals in Nigeria, was chosen as a case study. The various departments and users are interviewed and interacted with in order to, among other things, gather system requirements. The software development technologies used are ASP.NET with Visual Basic as language and Microsoft SQL 2005 Express Edition. The platform used is Visual Web Developer 2008 Express Edition. The web server used is Internet Information System (IIS).

Keywords: fault tolerance, information system, health institution, health care, case notes

1. Introduction

It may be no news the way health care providers and decision makers in the field are making good use of various social networks on the internet and through mobile telecommunication system for better information sharing. It, probably, would be an amazement to find out that some organizations have corporate web site on the internet without any corporate platform to manage in-house/internal business processes. Even in developed countries, one study of American health care providers, carried out fifteen years ago, showed that while 92% of health care professionals surveyed had informational Web sites, only 20% were participating in extranets or supply chain networks, and only 15% were currently offering enterprise/intranet portals (Wilson, 2000).

Though we talk of mobile technology as the future of health industry (Siau, 2003), we need something to build that future upon. The situation of things in health industry in some part of the world, especially the developing nations, is a contrast to what Scheepers and Damsgaard found out to be happening to organisations in as far back as 1997 which made them write: "Today's organizations are no less confused than in the past when it comes to managing the IT resource. Furthermore, the present technology landscape is quite different from that in the 1970's. Instead of being preoccupied with implementing payroll systems, database systems, or office automation systems, modern organizations are in the midst of assessing the competitive effects of the Internet, negotiating extranet solutions with business partners, and they are implementing intranets for internal use." In developing countries instead of modern organizations to be assessing the competitive effects of the Internet, negotiating extranet solutions with business partners, and implementing intranets for internal use, they are being preoccupied with implementing payroll systems, database systems, or office automation systems. The need for a robust highly faults tolerant intranet application system from software point of view is the driving thrust of this work.

2. Health Care Services And Information Systems

Contrasting health care service delivery industry with banking industry, the former could be described as information intensive and the later transaction intensive. Both industries have undoubtedly benefitted greatly from the use of computing, information and communications technology. Yet the open truth is that banking industry is much further advanced in this regard. The health care sector still lags behind the financial industry, the telecommunication industry, and the airline industry in terms of the implementation of information technology (Siau, 2003), especially in developing countries: Nigerian situation is a case in point. A transaction

based system relies predominantly on data. These are observations or facts which when collected, evaluated and organised to become information or knowledge. Data are computer input elements. Information on the other hand consists of data which are: "processed, organised or classified into categories to serve a useful purpose. Quoting Nobel Laureate Kenneth Arrow information is defined as 'a reduction in uncertainty'. Information as an intellectual construct is subject to constant change. Its importance depends on who makes any information based transactions and when. It is both resource and commodity but unlike matter and energy is not consumed by use. Communications is central to information flow and essentially subsumed in it. 'Information' depends heavily on 'information technology' (IT) but is a far wider concept, with educational, social, economic, employment and cognitive implications. Data, information, knowledge and intelligence ascend hierarchically. The concept of encoded data organised as 'information' is the common feature of genetics, biotechnology, language, communications, mathematics, electronics, computing and robotics". (The Parliament of the Commonwealth of Australia, 1991)

In the banking industry data consists of numbers whilst in the health care industry data takes many forms including numbers, text, concepts (coded data), graphics, images, physiological measures (signals), and sound. Health care professionals rely on all their senses, including smell to collect assessment data from individuals. These data are recorded in a person's medical history or health record. Now that technology has progressed to the point where all types of data, with the exception of smell, may be produced in digital form it has become feasible to develop fully integrated health information systems. This should assist greatly in meeting the functional needs for health information. Dick (1992) noted that 'we lack the evidence to make more informed decisions in health care today across the spectrum from the bedside up to the formulation of national health care policy'. He went on to say that "most of the evidence needed to make more informed decisions remains embedded in fragmented, irretrievable, and often illegible paper-based patient records".

3. Information Communication In Health Sector

To be able to have a comprehensive understanding of the extent of the intranet required to enhance information flow in an establishment it is just appropriate to know who are the stakeholders involved in the information flow, and from who to who.

The communication of information is fundamental to healthcare. In pre-history, it is documented in literature that knowledge and skills were passed from healer to apprentice by talking and example. Literature further reveals that early cuneiform writing on clay tablets record some medical techniques and remedies. In more recent times, medical books have documented an accumulating human knowledge. Currently, journals, magazines, books, proceedings and pamphlets deliver a daily avalanche of written healthcare information, while audio and video tapes, radio, television, CD-ROM, video-discs and films produce a mountain of audio-visual material. There is a well established communication between healthcare providers. Between the nurse and the doctor, the doctor and the pharmacist, the radiologist and the pathologist, and so on. A healthcare system must also be managed and funded. This requires a flow of information from the health care recipient and the provider to various organisations for fund and resource allocation, and for management.

All the above information is small compared to that which passes between the recipient of healthcare and the provider. This intercourse contains the daily application of healthcare. In it, and too often hidden, are the clues to new diseases, complications and interactions. Some clues are recorded. They form actual or potential food for researchers. Healthcare is about people and mostly one-to-one relationships between recipients and providers. However, the domain is steeped in information and its management. In this, technology will have an ever increasing role to play.

There is no point in applying information technology unless advantages result which out-weigh any associated disadvantages. Let us briefly consider some of these and the building blocks required for advances to occur.

4. Information Technology Tools In Health Care

According to Siau (2003), three basic sets of tools can be applied to health care industry: 1) Internet applications; 2) enterprise systems; and 3) mobile technologies. These various tools can be used by health care organizations to store internal organizational information based upon its different business modules, including finance and accounting, human resources, payroll information, etc. Also, health care organizations can use these numerous technologies to provide better patient care, by not only obtaining more information from patients, but also giving more information on self-care and disease management to patients. Better care can also be provided using such enterprise applications as decision support tools, PRM applications, information warehousing and mining, as well as Internet applications such as telemedicine, which can be used to personalize care and make care more convenient for patients who can access information from anywhere.

Patients' Information: Case Note: The health management information system (HMIS) has been defined as a system that provides an appropriate information support to each decision making level of the health care delivery system. Central to this is the patient's Case Note: a folder or file with various and multiple pieces of information that apply to the patient. These informational items are cross departmental in origin, they are however meant to be available in due time for appropriate health care evaluation, intervention and management by the care givers and other stakeholders. The following is a comprehensive list of the content of a patient's Case Note as found in the institution taken for case study and used for the application software herein developed. In this work, effort has been made to cover everything that a patient's Case Note will likely have:

Biometric/Demographic Information Details, Continuation Sheets, Nursing Process Sheet, Medication/Drug Charts, Intake/Output Chart, TPR Chart, Laboratory Investigation Results, Payment Evidence/History, Consultation Request Form, Referral Letter, Operation Notes, Treatment Sheet, Other General Documents

5. Fault-Tolerance Techniques In Health Sector Information System

Looking up the words "fault" and "tolerance" in Oxford English dictionary, we can define "fault" as something that has the capacity to detract from the integrity, functioning, or perfection of something else (Microsoft, 2010), or as a malfunction or deviation from expected behaviour and "tolerance" as the capacity for enduring or putting up with something. Putting the words together, "fault tolerance" refers to a system's ability to deal with malfunctions (Krzyzanowski, 2009).

The most widely accepted definition of a fault-tolerant system is that it is a system which has the built-in capability (without external assistance) to preserve the continued correct execution of its programs and input/output (I/O) functions in the presence of a certain set of operational faults. An operational fault is an unspecified (failure-induced) change in the value of one or more logic variables in the hardware/software of the system. It is the immediate consequence of a physical failure event or user wrong interaction with system. The event may be a permanent component failure, a temporary or intermittent component malfunction, or externally originating interference with the operation of the system. "Correct execution" means that the programs, the data, and the results do not contain errors, and that the execution time does not exceed a specified limit. An error is the symptom of a fault, i.e., it is the change in an instruction or a data word which is caused by the presence of a fault at the point of the physical failure event.

The above definition of a fault-tolerant system is based on the premise that the system will function correctly when operational faults are not present; that is, it postulates that design faults have been eliminated from the system prior to its use. A more general interpretation of fault tolerance also includes the ability to tolerate thus-far-undetected design faults. Design faults occur both in hardware and in software of the system. They are the consequences of either:

1) an incomplete or incorrect specification; or

2) an incorrect translation of the specification into the final design-the assemblies of components or the sequences of machine language instructions and sets of data words.

In order to tolerate left-over design faults, the system needs provisions to recognize their presence and to deactivate the affected hardware or software while program execution continues using the remaining parts of the system. In the strict sense, a system is fault-tolerant only if external assistance is not required to implement its fault tolerance. Most of the current-generation computers require manual assistance; however, it must be noted that nearly every computer employs some fault-tolerance techniques, such as microdiagnosis, parity checking (Maitra, 1996), watchdog timers, etc. The fault-tolerance process is interrupted at the point at which a maintenance specialist takes over the control of the system. An off-line replacement or repair of deactivated parts of the system is acceptable in a fault-tolerant system, as long as the correct execution of programs is being continued without external intervention.

5.1 Fault Tolerance And Patients' Information (Case Note) Movement

The movement of patients' information between stakeholders as found out in the case study is as delineated in Figure 1. Interaction with several stakeholders in the information flow depicted in the figure, including the patients themselves, revealed the need for a keener look at the system in the light of tolerant to fault, having in mind the critical nature of the data contained in the Case Notes. There were very many reported cases of missing files, some of these Case Note losses might be due to miss-filing or any other probable causes. The implication of missing Case Note is huge: this means loss of the patient's medical history. Another thing noticed with this system is high patient waiting time – it takes relatively significant time from the time a case note request is initiated and the time it is made available at the point where it is needed.

5.2 Fault-Tolerance Techniques In Health Information System

Reliability and availability have become increasingly important in today's computer dependent world. It has been severally established that in many applications where computers are used, outages or malfunction can be expensive, or even disastrous (Nørvag, 2000), health domain can be said, arguably perhaps, to be among such application areas.

In designing a fault-tolerant system, archiving 100% fault tolerance may be only a theoretical possibility which can be very hard, if not impossible, to come by in reality (Krzyzanowski, 2009). Moreover, the closer we try to get to 100%, the more costly our system will be.

To design a practical system, one must consider the degree of replication needed. This will be obtained from a statistical analysis for probable acceptable behaviour. Factors that enter into this analysis are the average worst-case performance in a system without faults and the average worst-case performance in a system with faults.

Availability refers to the mount of time that a system is functioning ("available"). It is typically expressed as a percentage that refers to the fraction of time that the system is available to users. A system that is available 99.999% of the time (referred to as "five nines") will, on average, experience at most 5.26 minutes of downtime per year. This includes planned (hardware and software upgrades) and unplanned (network outages, hardware failures, fires, power outages, earthquakes) downtime.

Five nines is the classic standard of availability for telephony. Achieving it entails intensive software testing, redundant processors, backup generators, and earthquake resilient installation. If all that ever happens you your system is that you lose power for a day once a year then your reliability is at 99.7% ("two nines"). You can compute an availability percentage by dividing the minutes of uptime by the minutes in a year (or hours of uptime by hours in a year, or anything similar). For example, if a system is expected to be down for three hours a year on average then the uptime percentage is 1-(180 minutes / 525600 minutes) = 99.97%. The following table shows some availability levels, their common terms, and the corresponding annual downtime.

Table 1: Availability Classification

Class	Availability	Annual Downtime
Continuous	100%	0
Fault Tolerant	99.999%	5 minutes
Fault Resilient	99.99%	53 minutes
High Availability	99.9%	8.3 hours
Normal Availability	99 - 99.5%	44-87 hours

2.5.1 Approaches to faults

Literature overview reveals three basic approaches to fault given in the acronym ART:

Fault Avoidance: We can try to design systems that minimize the presence of faults. Fault avoidance is a process where we go through design and validation steps to ensure that the system avoids being faulty in the first place. This can include formal validation, code inspection, testing, and using robust hardware.

Fault Removal: is an ex post facto approach where faults were encountered in the system and we managed to remove those faults. This could have been done through testing, debugging, and verification as well as replacing failed components with better ones, adding heat sinks to fix thermal dissipation problems, et cetera.

Fault Tolerance: is the realization that we will always have faults (or the potential for faults) in our system and that we have to design the system in such a way that it will be tolerant of those faults. That is, the system should compensate for the faults and continue to function.

6. Conclusion

Approaching health information system in such a way that will employ all the approaches of fault described above (ART) is undoubtedly a veritable necessity, considering the critical nature of health industry. Application of technology in medicine, and health sector generally, should not be only in terms of procurement of specialised equipment and machines, the advancement in deployment of technology should not be only in developing e-commerce information applications only. Health sector is undoubtedly a data critical field that requires exchange of life and death information about a "specimen" - human being - among care givers, thus the great need for an information system flow platform that supports highly fault tolerant information sharing procedure towards appropriate timely intervention by care givers in the cause of preserving life, most particularly in developing

countries. Health care system in developing countries could be greatly enhanced to deliver better service to humanity with the appropriate political will. It is highly recommended that Nurses and Doctors and other care givers be provided with better input devices than the traditional keyboard and mouse: such input devices that will facilitate easy conversion of hand-writing to text will be a great tool for the users of the application. This will surely reduce the time it takes to type text as may be required, for many care givers were found to have greater preference for hand writing to keyboard or mobile device typing.

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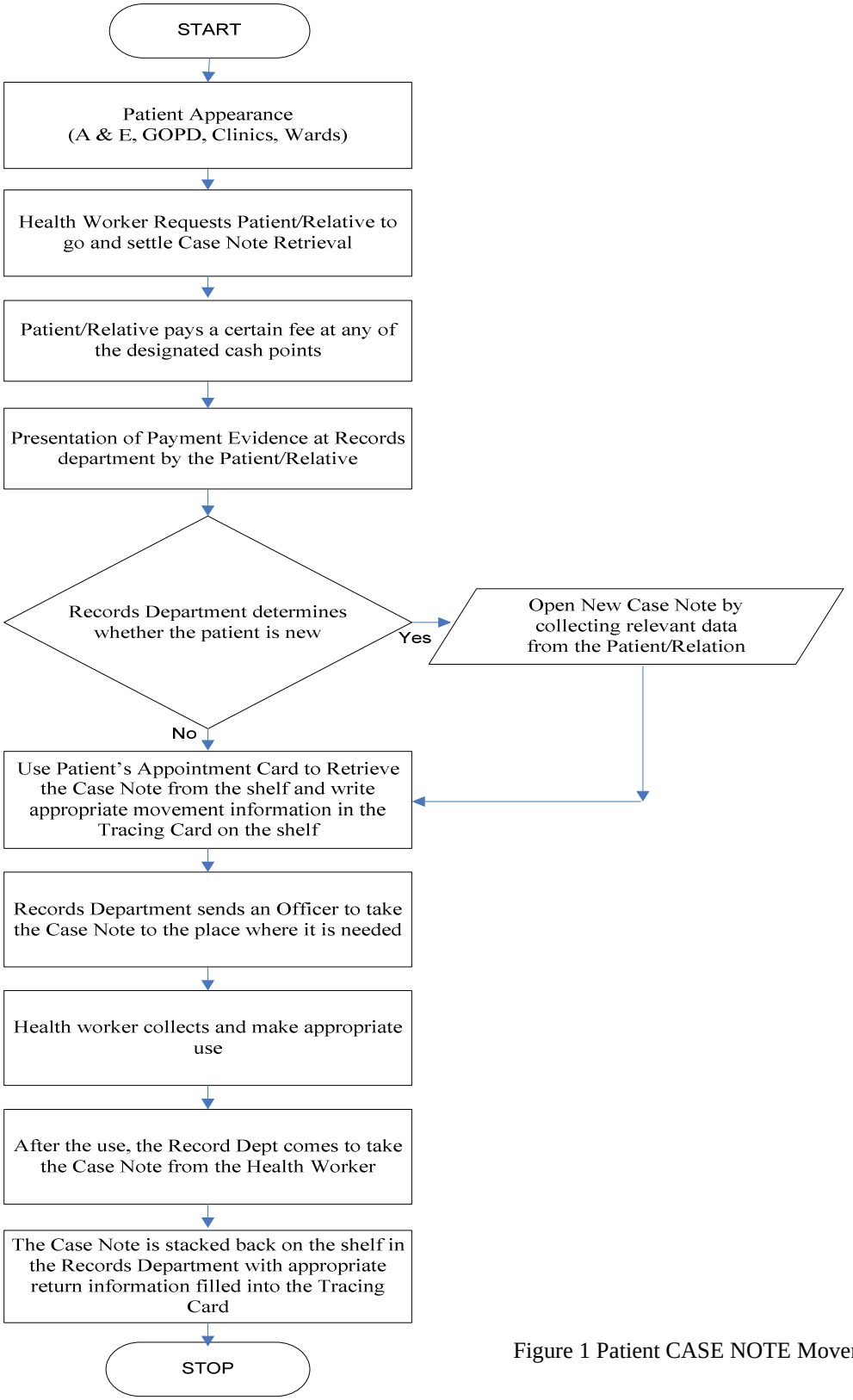

Figure 1 Patient CASE NOTE Movement Flowchart

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