Evolving the Telecommunications Industry: Context Aware Systems, the Primer for User Centered Services

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***Abstract*—Convergence in telecommunication industry provides an excellent platform for context aware services. Context Awareness, being able to harvest environmental information, can promote personalised applications and services that are closer to the consumers. In this paper, we will explore the relevant research studies that had been done to surmise a relatively complete set of functionalities that is required to realise a context aware system.**

***Index Terms*—context aware, user centric, convergence**

I. Introduction

THE telecommunication industry has experienced several waves of changes from the introduction of wired telephony to wireless telephony and is currently heading towards fixed-mobile convergence. An All-IP network such as 21st century network of British Telecommunication plc makes fixed-mobile convergence a reality and provides an excellent platform to enable the context aware services.

Many of us may have heard of "context awareness" by now. Context awareness, in short, means the capability to utilise environmental information including user's information to provide a truly user centric environment. Some of the companies in the telecommunication industry are already using presence information such as user location to improve user experience. Nevertheless more can be expected from the free flow of context information around us. With the continuous advances in sensor technology and the emergence of wireless sensors network, context aware systems will become reality in the near future with powerful capabilities.

Many of the research studies done in context awareness space are focusing only on single perspective such as event-trigger context service. However, the power of context aware systems is not bounded by one perspective. Each context aware system is expected to be interconnected with one another to exchange context information for context information integration. By having all context information (user status information, environment information, user historical information, user preference information, security information and etc.) integrated and available to the context aware service, the context aware service could "understand" the user better, whereby be able to provide a more dedicated service.

In this paper, we will provide a summary of relevant research studies that has been done, highlighting each of their approach and provide a relatively complete set of functionalities that is required to realise a context aware system.

II. Factors of Convergence in Telecommunications

Convergence has been taking place for years now. A study performed by the European Commission [1] defines convergence as allowing both traditional and new communication services, whether voice data, sound or pictures to be provided over many different networks. An excellent example of convergence in the telecommunications industry is the IP Multimedia Subsystem (IMS).

Today's communications experience, whether at work or at home, is of diverse communications services comprising traditional fixed-line telephony, mobiles, voice-over-IP, text messaging, instant messaging, email, voice instant messaging, push-2-talk, and on-line forums, to name but a few.

Although there are some clear similarities amongst these communications services, at least in terms of the style of communication enabled, they exist because they are often associated with particular types of device and network infrastructure.

However, these communications services are evolving and we can already see the first signs of how they will converge to offer users an integrated communications experience (Fig. 1). Email is now available on mobile devices, text messages can be received on home phones, and voice calls can be made from a mobile phone routed over a wireless local area network, transparently to the user.

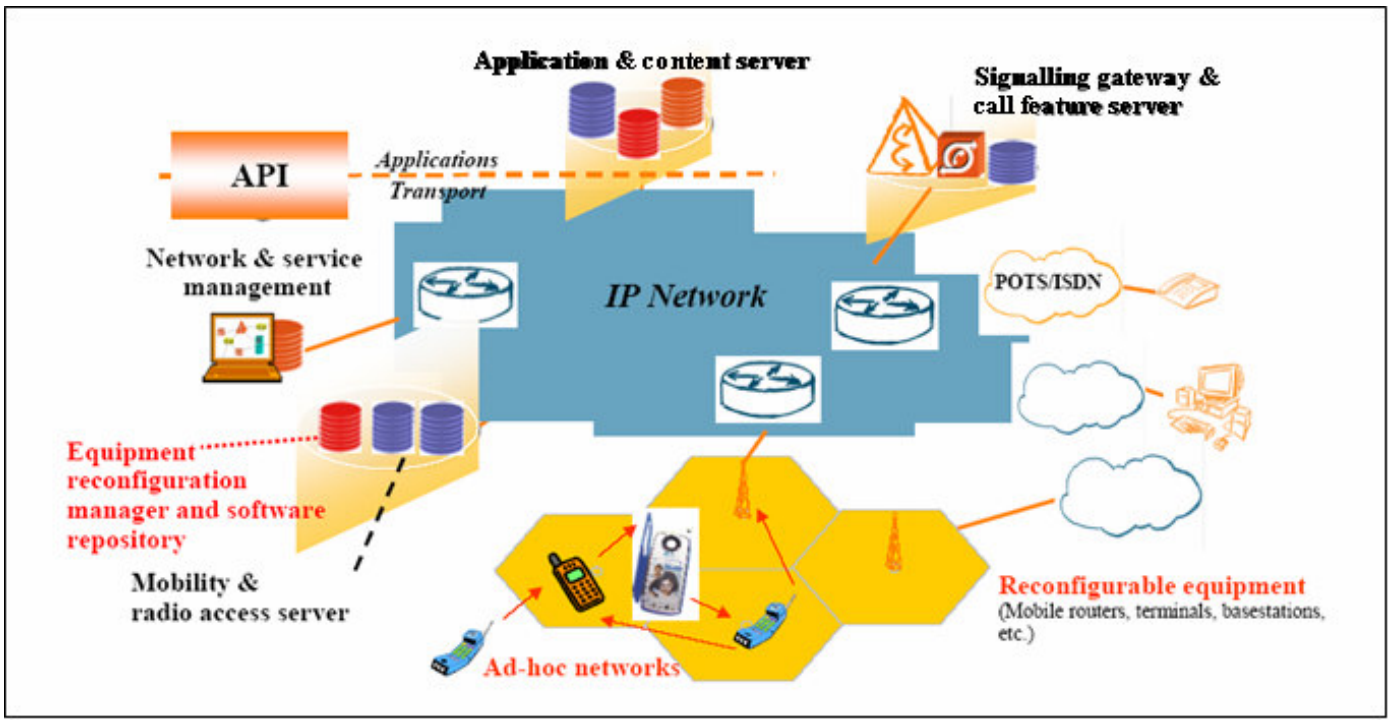

Fig 1 Convergence In Telecommunications

We have reached the point where it is within reason to expect a personal communications device that can connect to any type of network - mobile networks, IP networks or even the PSTN (the latter two via Bluetooth, WiFi or WiMAX) – and that can support any or all of the voice and text-based communications services.

However, this does raise an important question: as individuals do we really want eight (at least) different communications services at our disposal? That is three ways of making a voice call, two walkie-talkie style services, and three text-based services. To accentuate this, would not individuals want to use the best way of utilising the best device to communicate, on the best network for the services/application used at that specific moment in time? How does the environmental context around affect how an individual prefer to communicate?

III. Bridging the Technology-Human Gap

The WWRF's 'Book of Visions' places a lot of emphasis on machine-to-machine, human-to-machine and machine-to-human applications – areas that have not been explored extensively until now. It is believed that future communication services will adapt to an individual's requirements [2]. Most of us would be familiar with the acronym WYSIWYG (What You See Is What You Get). This belief is slowly changing, where in future individuals would expect much more …"What You Need, When & Where, Is What You Get".

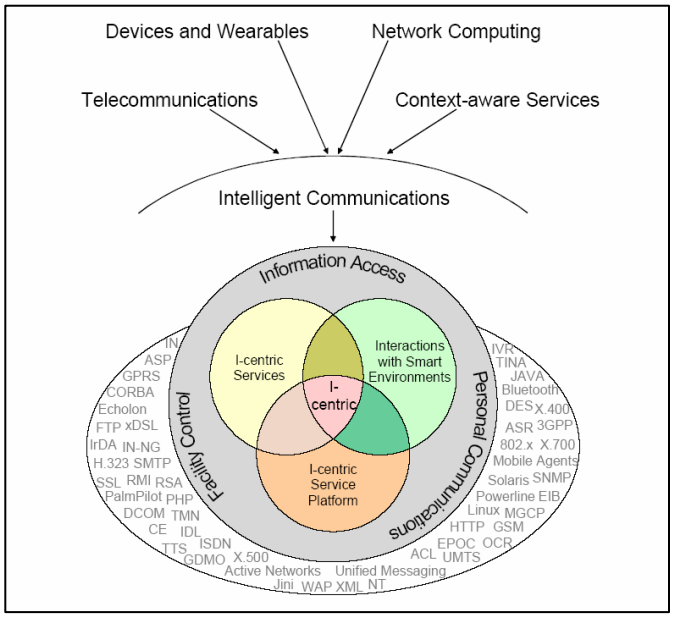

Fig 2 Enabling Technologies

System and application designs today are mostly technology driven because of the lack of tools to incorporate user behaviour as a parameter in the product development process. In order to create systems and services for future communications needs from the users' point of view, there is a need to better understand the user and what identifies the user interaction experience. Figure 2 illustrates a combination of enabling technologies which will promote the future of intelligent communication.

IV. Context Awareness Uncovered

Context Awareness has become one of the hot topics in recent computing research. Context Awareness is an attempt to utilise any relevant information that could help to provide services to user in a more proper and accurate manner. The idea of context awareness could be considered to be started in early 1900s. In 1991, Mark Weiser introduced the term "Ubiquitous Computing" with the meaning of seamless integration of computing devices into user's daily life [3]. Evolving along the path of ubiquitous computing, Want et al introduced Active Badge Location System in the following year [4]. The Active Badge Location System is using infrared to track user location to forward user's telephone call. The term "context aware" is first introduced by Schilit and Theimer in year 1994 [5] to address the ability of system to discover and react to the environment changes.

From the history of Context Awareness, the Context Awareness is one of the branches of Ubiquitous Computing and became one of the key for the success of Ubiquitous Computing. Since the introduction of the context aware computing, many studies have been carried out and many researchers try to provide an accurate definition for the term "context". Until present time, the most accurate definition is provided by Dey and Abowd in 2001 [6]. Dey's definition of context is:

"Any information that can be used to characterise the situation of entities (person, place or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves. Context is typically the location, identity and state of people, groups and computational and physical objects."

The true power of Context Awareness does not depending only on the knowledge of the situation of entities or the status of the application. The fact is that the ability of context aware system to relate information together even when the information may seem irrelevant. The capability to expand from a piece of contextual information to a group of relevant information helps the context aware system to understand the situation from multiple aspects. Such capability has given the context aware system the true intelligence in its functional domain.

V. The Essence of Context Aware Systems

Within majority of the studies on context aware system, the research on context awareness could generally be categorised into two categories: Context Service Creation and Context Middleware Development [7]. The Context Service Creation focuses on the effort to create context services and the potential model to utilise available contextual information. The Context Middleware Development on the other hand is creating a standardise platform that could support the need of context aware system. The middleware handles the general functions such as contextual information sensing, processing and storages for the context aware system.

A. Context service creation

Schilit's System Architecture [8] is a distributed mobile computing system architecture that has been experimented by William Schilit and his research group at Xerox PARC. This architecture has divided all available information into three large groups as user agent that encapsulate all private and individually distinct context information of each user, device agents that represent all computing devices in the context as they contain device information such as device connectivity or access control. Lastly, it is the location directory service – active map, which allows the application to keep track of all location and context information by using queries.

However, Schilit's work has limited notion of context and neglects on the notion of time or activity information. What makes it less flexible is that [9] the user and device agents need to be rewritten if there is an addition of user or context information. Even though this architecture supports querying and notification mechanism for context delivery, it still provides very little support for discovery of components that the applications would like to process on. Instead, just like processing additional user and context information, it requires extra work of locating the components explicitly before querying or processing. Yet, Schilit's work has become the fundament of a lot of research works running active in ubiquitous computing field nowadays

Dey and Abowd have defined Context Toolkits in 1999 to create a framework for the Context Aware application development [10]. In the architecture, the context toolkits have three primary components which are widgets, aggregators and interpreters. These three components provide the abstraction to the context aware application on contextual information. The widgets are the source of contextual information, it extracts contextual information and translates raw data from sensors that are monitoring the environment. The interpreters will then further derive the information to more meaningful higher level contextual information. Lastly the aggregators help to aggregate the contextual information to minimise the complexity of context aware applications. Although the paper of Day and Abowd define the framework for Context Aware application development, they do not define the contextual data modelling.

Java Context Awareness Framework (JCAF) is another framework that serves the purpose to assist in Context Aware application development [11]. JCAF has the objective to create a general-purpose, event-based and distributed service oriented Java Framework. The core design principles of JCAF are based on the following beliefs:

1. Contextual information is scattered everywhere in the environment and some of the contextual information is stored at remote location.
2. Each contextual service may require services from each other.

3. Contextual information is the changes that happen in the environment including the changes of user activities.

JCAF introduced Context Monitor to handle sensors that are monitoring the environment and Context Actuators to handle deployed actuators as the response on changes. In the interpretation of JCAF, context is considered as a container that is storing context item where the entity in the context is one of the context items. Each context item within the context container is related to each other.

B. Context middleware development

Ranganathan and Campbell created an agent-based context aware middleware using ontologies[12]. They describe the context data as predicate using ontologies in the form of ContextType(subject, verb, object). In this middleware, they introduced 3 types of agents:

- context provider
- context synthesizer
- context consumer

The context provider is acting as the interpreter that provides other agents translated context information. The context synthesiser plays both the context provider and consumer roles where it adds in more logic to generate new context from the raw information from context provider. Lastly, the context consumer is the application agent that utilises this information to adapt their behaviour. Each context consumer will query the context provider through a lookup service.

The agent-based middleware is using Gaia as their infrastructure for ubiquitous computing environment. The Gaia, created by Roman et al [13], is a distributed middleware infrastructure that coordinates software entities and network devices. It exports services to query and utilise existing resources. The objective of Gaia is to provide a framework for development of user-centric and context sensitive mobile application.

Chen et al has introduced Context Broker Architecture (CoBrA) for supporting the context aware systems [14]. The CoBrA is an intelligent contextual information broker that could share all contextual data. The intelligence of this broker came from the use of Semantic Web Language (such as RDF) to model the contextual information and the use of Web Ontology Language (OWL) to perform intelligent reasoning. Computer system that could understand Semantic Web Language will be able to trace through the ontology. This capability allows such computer system to perform automatic reasoning. On top of the intelligent reasoning, CoBra governs the contextual information sharing model through the implementation of policy language to control sharing level of user information.

Service-Oriented Context-Aware Middleware (SOCAM) is a middleware architecture that targets to enable rapid prototyping of context aware services [15]. SOCAM models the contextual information based on the ontology using OWL to resolve the issues of semantic representation, context reasoning, context classification and dependency. SOCAM define ontology in OWL to enable it to describe context semantically which is independent from any programming language and enabling computer system to understand the semantic value. This combination of technology enables the formal analysis on domain knowledge that could be done automatically by the computer system. A set of independent services is provided within SOCAM to facilitate the context aware applications and enabling contextual information exchange with other context providers. These services provides the fundamental functionalities such as context acquisition, context discovery, context interpretation and context dissemination.

C. Context Aware Service Platform

In our opinion, after studying the existing researches and surveys on context aware system [7], [16], the key for the success of context aware systems depends on its supporting systems, which is the context aware middleware. We introduce the Context Aware Service Platform that could assist the context aware service provider in the execution of their services. The platform will provide the fundamental required services as an abstraction layer for the developed context aware services.

The provided services are:

- Context Sensing - Context Sensing is the service that will monitor the sensors and devices either through passively listen for their status changed report or actively query on their status periodically
- Context Modelling – Context Modelling is the entrance of a piece of context information into the core context processing components
- Context Association - Context Association is responsible to explode single piece of context information into multiple related context information pulling from various source
- Context Optimisation - Context Optimization is the process of resolving information conflicts and filtering of context information. It is a context aware service sensitive process as each optimization outcome for each context aware service may vary depending on their nature
- Context Exchange - Context Exchange is important service to allow the context aware service platform to exchange context information with other platform. This functionality enabling this platform to scalable
- Context Storage and Retrieval - Context Storage and Retrieval service will keep a record of each context information for future retrieval whenever required

By having the platform to take care of the fundamental problems, context aware service providers could focus entirely

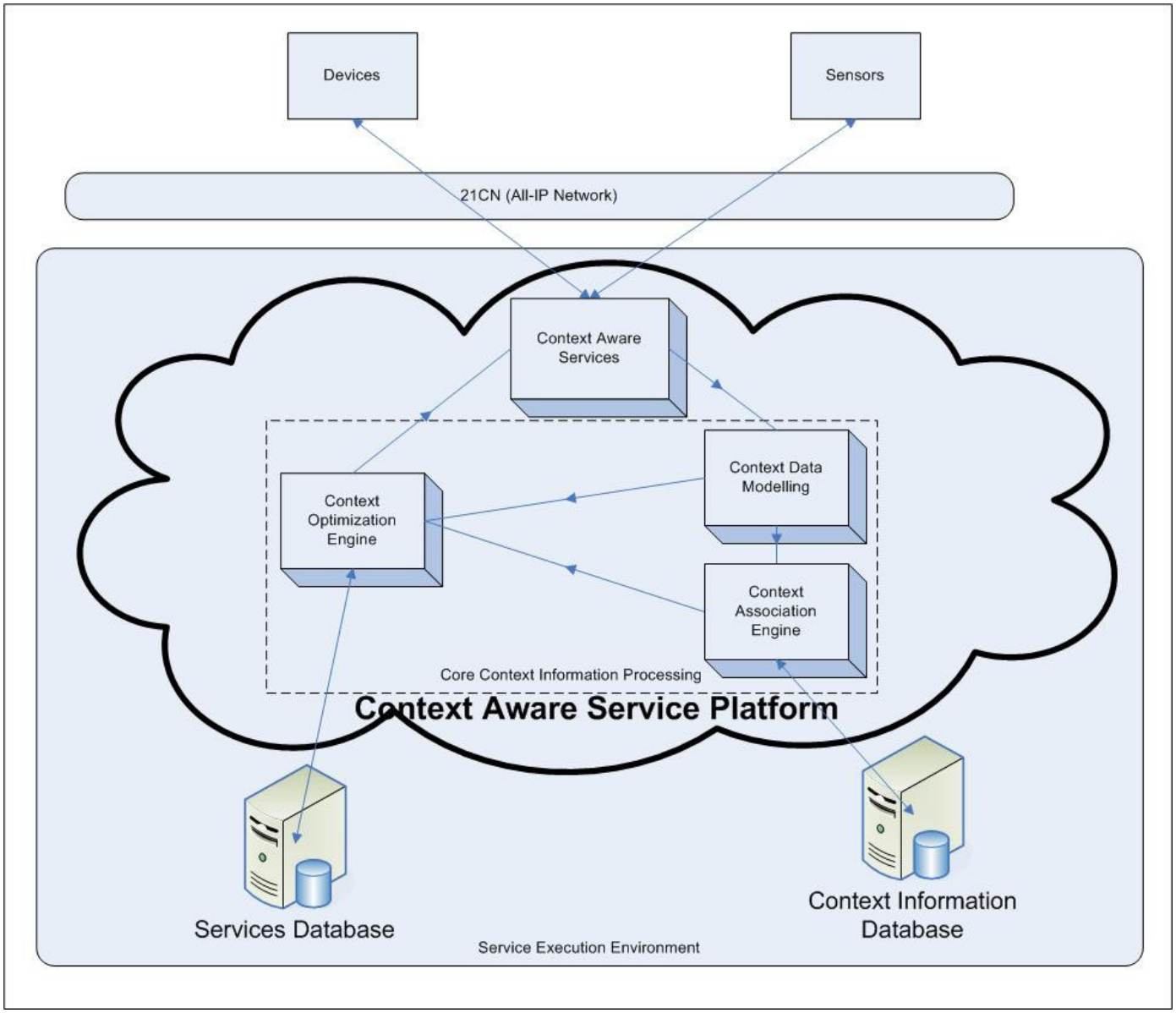

Fig 3 Context Aware Service Platform

on the service execution logic. Figure 3 shows the logical view of the platform.

The Context Aware Service Platform has made an assumption that everything is located within all IP-based networks where everything could be located through IP networks. 21st Century Network (21CN) offered by British Telecommunications plc (BT) is one of the examples. The component of Context Aware Services in Figure 3 includes the provided fundamental services. The rationale of including those services in that component is due to the concept of service-on-service which provides a layer of abstraction to the actual invocation allowing for higher flexibility and portability.

The context sensing service is located within the context aware services component and does not considered as a part of core contextual information processing. The sensors for contextual information are not restricted to only the physical sensors, a software based sensors for monitoring the system status are included in the definition of sensors too. Sensors are not the only source for contextual information. Contextual information may source from devices or user's input which makes it more logical to deploy context sensing service in the context aware services component.

Contextual information gathered from context sensing service is relayed to Context Data Modelling component for modelling and formatting. The Context Aware Service Platform is using a single format for the contextual information within its core processing components. The Context Association Engine will discover all related contextual information which is the current available contextual information and the history contextual information from the

Context Information Database. A copy of the current contextual information will be saved into the Context Information Database.

The Context Optimisation Engine gathers all related contextual information from the Context Data Modelling, Context Association Engine and Services Database to determine the Context Focus for context aware service. Only by determining the Context Focus, the engine could measure the Degree of Relevant on every piece of contextual information. The optimisation engine will ignore contextual information that is not relevant to the Context Focus or has minor effect. The optimisation process is a must to minimise the processing time and avoid information overload on the context aware services.

To understand the definition for Context Focus and Degree of Relevant, we shall understand the user multi-sphere model (referring to the Multi-sphere reference model in Book of Vision [2]) as illustrated in Figure 4. Each user is believed to have multi-sphere surrounding them. In Figure 4, the user has three spheres which are personal, local and environment spheres. The personal sphere contains the objects, location or information that has immediate relationship to the user. The local sphere which could also be known as moment sphere (moment sphere for describing the information) is the placement for things that do not have immediate relationship to the user. The last sphere, environment or background sphere (background sphere for describing the information), is for everything else that exists but may not have relationship to the user. Therefore, as it moves from user towards the environment sphere, the degree of relevance for the user is fading and at some point might be complete irrelevant. The Context Focus adopts the multi-sphere concept. Instead of only having user as the centre of sphere, we extended the multi-sphere concept to contextual information. The Degree of Relevance is the measure of how relevant a piece of information could be to the Context Focus. Once the Degree of Relevance is determined, the optimisation engine could filter out some of the contextual information.

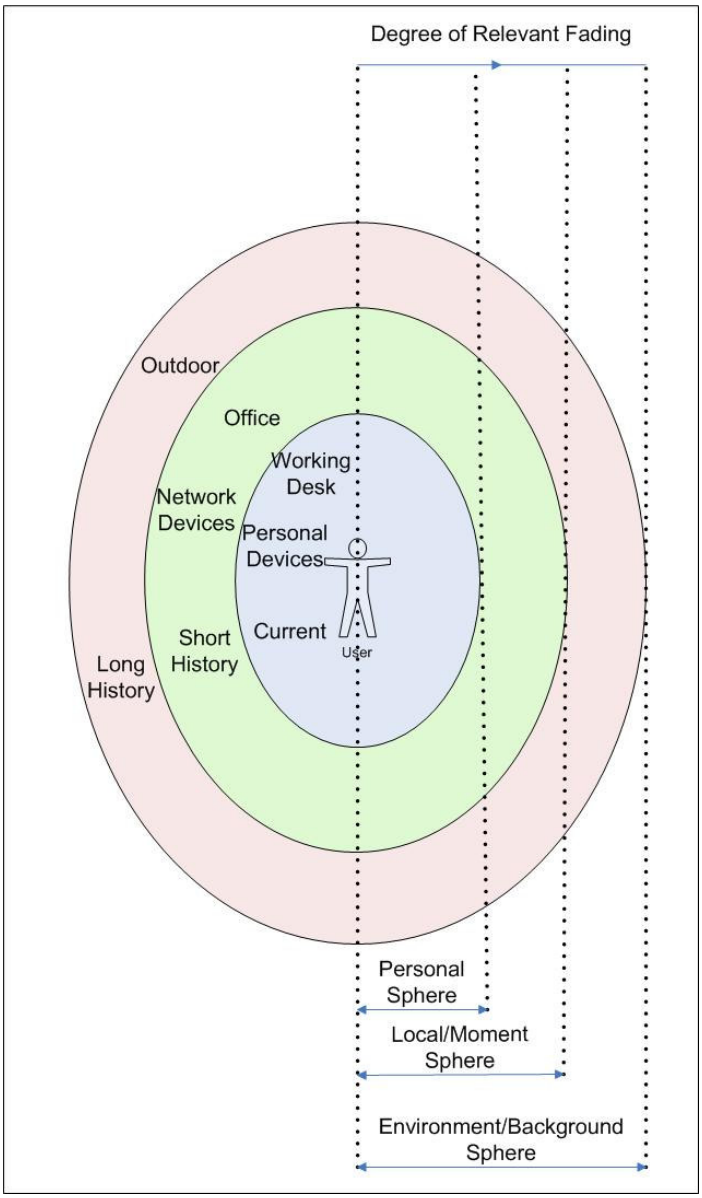

Fig 4 User Centric Multi-Sphere Model

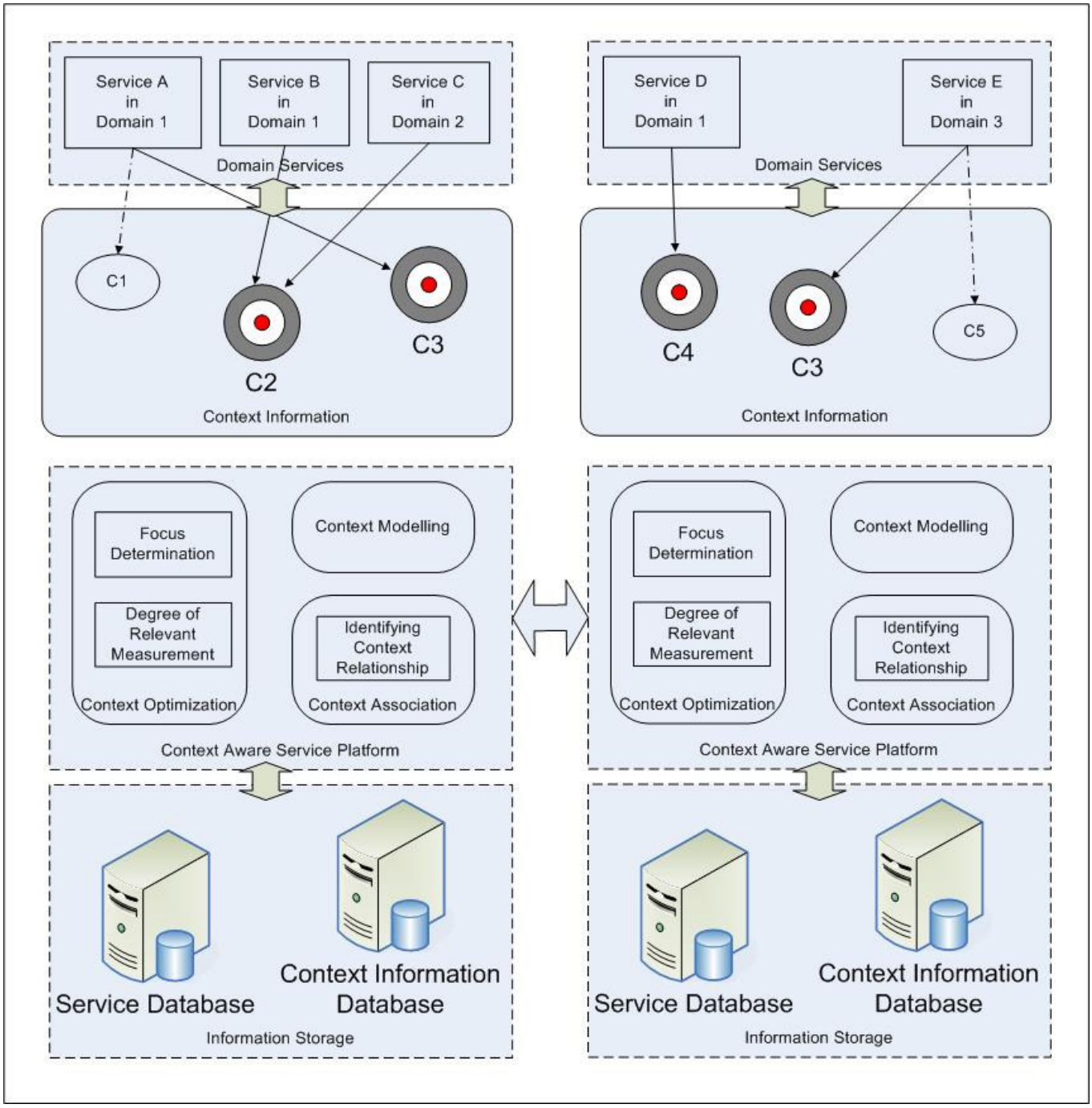

Fig 5 Context Aware Service Platform Architecture

The Context Aware Service Platform is designed to be scalable and capable to exchange contextual information with other platform. Figure 5 is an illustration of Context Aware Service Platform architecture and the context aware services deployment on the platform. Various domain context aware services are deployed on the Context Aware Service Platform. Although services may be in the same domain, different services may have different Context Focus (service A, B and D in Figure 5) and services from different domain may have the same Context Focus (service A and E in Figure 5). The components in Context Optimisation (Focus Determination and Measurement of Degree of Relevance) are assisting the context aware services in determining the relevant contextual information. The platform exchanges contextual information at the core contextual information processing mainly through the Context Association Engine. Whenever Context Association Engine receives a piece of contextual information, its internal component will expand the contextual information to find all related information. It could retrieve the contextual information from Contextual Information Database and request contextual information from other platform.

VI. 21CN AND HOW CONTEXT AWARE SYSTEM WOULD INTERACT WITH AND ENHANCE SERVICES WITH BT'S NEW INFRASTRUCTURE

We see a multitude of connected devices infiltrating our homes, outdoors and our workplace. These connected devices bring us somewhat closer to the services and applications that any provider would like to sell as our communication device would have a multitude of connection choice, hence being always connected. Nevertheless, some elements are still missing to provide the user the experience that is required.

21CN is BT new all-IP network that provides converged services for user enhanced experience, which is identical to the objective of Context Aware Service Platform. 21CN provides services which generally fall within four functional categories, which includes Family&Friends, MyWork, EntertainMe and HelpMe. Figure 6 demonstrates how Context Aware Service Platform could integrate with 21CN. In Figure 6, the Context Aware Service Platforms are linked together as Context Aware Service Network which is a cluster of platform where each of them may focus only on a selected domain.

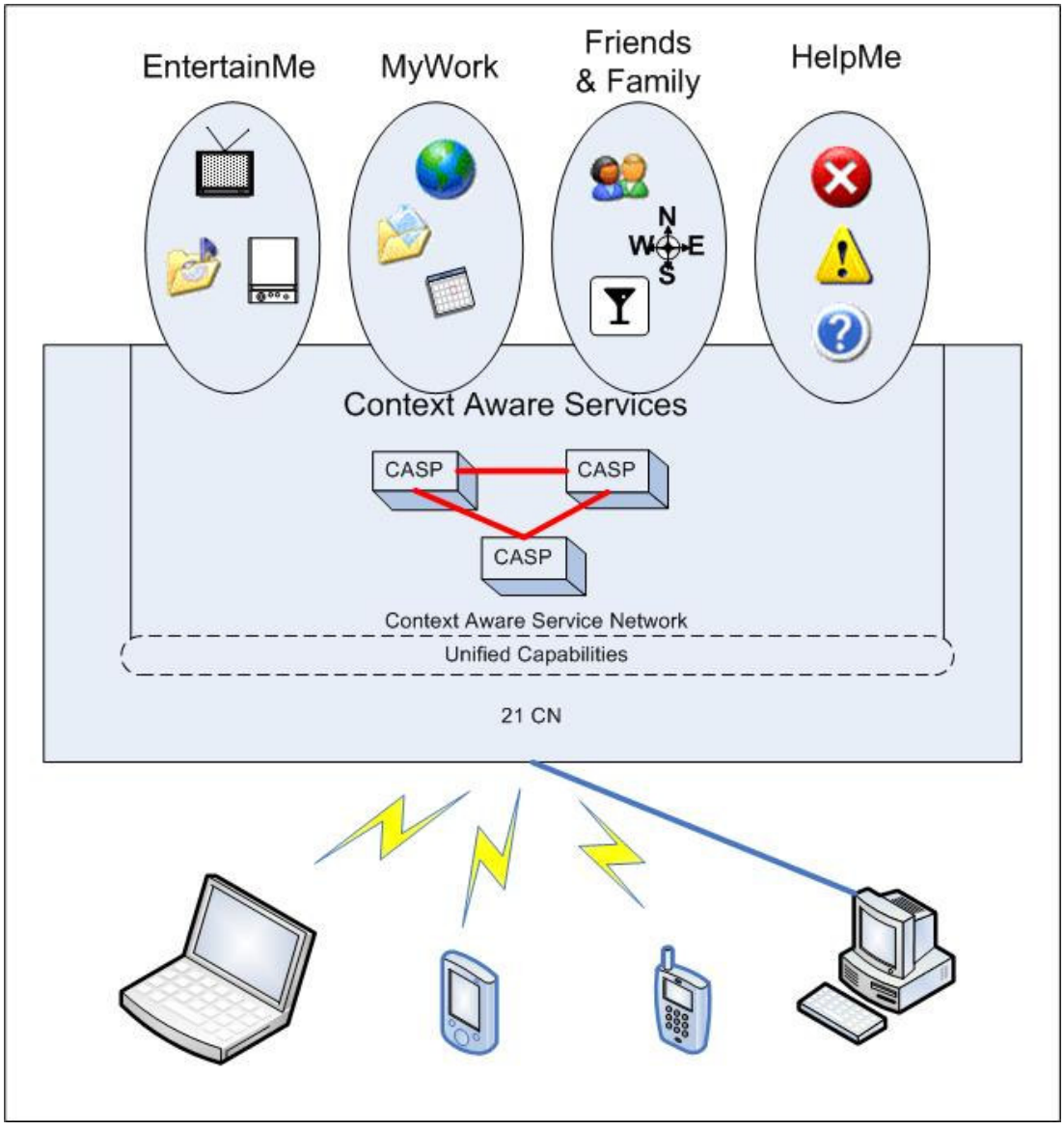

Fig 6 Context Aware Service Network with 21CN

The Context Aware Service Network could become a component within 21CN service execution environment that is functionally integrated with the 21CN's Unified Capabilities. By chaining the Context Aware Service Platforms, each platform's autonomous contextual information processing capability is combined into one major intelligence source for the 21CN.

The Context Aware Services are not restricted only with presence information as they include a wide range of information as their service execution references, allowing the services to understand the user's true needs and the desired delivery of services. The Context Aware Services could be the

- system level intelligence diagnostic that could find out the missing or damage components,
- friend-locating that enables one to know friends' status and location,
- intelligence meeting planner that could ensure the availability of required equipments and
- movie recommendation that could recommend titles based on the user video profile.

The Context Aware Service could assist its user to handle their daily task easier and provide accurate and appropriate alternative delivery channel to the user.

VII. CONCLUSION: A FUTURE TO LOOK FORWARD TO …

BT's focused strategy on embracing the Next Generation Networks in the 21st Century Network has sparked many opportunities for the future of telecommunication. If history had its way, we shall see the 21CN bringing rapid growth to the telecommunication industry as seen in the IT world. Having an All-IP infrastructure will enable telecommunications industries to manoeuvre better in the harsh world of survival of the fittest. We have seen many IT companies impinging into the realm of telecommunications especially with the growing popularity of Voice over IP and the concerted efforts to make these services more robust and reliable.

The context aware service platform is the promising enabler for rapid context aware service creation and the foundation for the context aware service execution. Context aware services, when made available enabled by the platform will be greatly valued by users.

Users will be in a more interactive environment that could help them to take care of small yet related matters automatically. Any possible devices around us could be used to bridge any services to the user, giving them the familiarity they preferred. The interaction between user and the devices will be in a more natural manner. Users would always have the option to alter the service execution or switch it off anytime they like.

Meanwhile from the network perspective, knowing the situation of the network and each network node's role could enable an adaptive and intelligent network. The capabilities such as self-healing, autonomous utilisation optimisation and self-reconfiguration to adapt for changes could also be enabled with context sensitive service logic.

The context aware service platform provides a stable and robust environment for the context aware service developers and operators. This stable environment is extremely important for them to have the accurate anticipated outcome and have the flexibility on changes. On top of the stable environment, the platform will be assisting the service execution to reduce the complexity for the service creation.

Following on the context aware service platform, the potential research area could be on finding an efficient solution to link up the context aware service platform forming the context aware service network or the finding on context aware service dynamic generation using existing functional components.

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