Context-aware Remote Healthcare Support System based on Overlay Network

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Abstract: Many countries are facing an ever-growing need to supply constant care and support for their disabled and elderly populations. So the importance to remote monitoring is becoming essential for looking after them. With an environment full of smart and cooperating artifacts will at the same time pose great risks to personal privacy. To protect personal information patient's data should be available irrespective of their location, but only to the authorized person. At the same time quality and reliability of transferring data is also important depending on the content of the data and the recipient. In this paper we propose a system where a personalized overlay network will be built in an ad hoc basis and links between different entities will be established according to the social relationship between the person under observation and the people at the other end and the situation of the observed person. The connected links will provide reliability, quality and other required characteristics according to the requirements specified by the members involved. For efficient cost and resource utilization, an on-demand network connection is considered for our proposed context aware ubiquitous healthcare system.

Key-Words: Adaptive context aware, Overlay networks, Ubiquitous healhcare, Multi-agent system, Security

1 Introduction

Many countries are facing a pressing social issue regarding ever-growing need to supply constant care and support for their disabled and elderly populations. Over the past 30 years, the number of Europeans over 60 years of age has risen by about 50 percent, and now represents more than 25% of the population. Within 20 years, experts estimate that this percentage will rise to on-third of the population, or more than 200 mil-

lion people [1]. With the shift toward nuclear families, more and more these elderly people living on their own.

Advancement in sensor, information and communication technology can play an important role in achieving cost reduction and efficiency improvement in health-care delivery systems, to the extent that this offers high-quality medical service anytime and anywhere, compare to conventional health-care systems that utilize a central server for the look up of information.

We are in the beginning of the era of ubiquitous computing society, where our daily lives are gradually becoming more and more dependent on various types of telecommunications. Recent progress in ubiquitous computing technologies makes it possible for anyone to access information, anytime and from anywhere. Broadband convergence with mobile and broadcasting networks has been accelerating the process of accessibility of such information.

In this paper we propose a model for secure and personalized health-care support system where the patient is equipped with a wearable sensor device. The online data of that person is stored in a video database and also can be available real-time to the respective person if necessary in an on-demand way through live streaming.

The general health-care information along with Health-care database and training records which will be stored in a different database can be accessed by the person responsible for specialized in those specific areas, like Instructor of the training gym or Health care Advice Agent. Now, as these information are not considered as sensitive data nor an emergency information, they can be transferred through low security, medium throughput path. Whereas, personal medical record database, which only doctor has the access and if necessary can be conveyed to the family members are transferred through high-security path. And if required high quality video image also need to be transferred to the doctor in emergency situation. So depending upon the information and to whom it will be transferred we need different levels of security and bandwidth requirement of that path. So while establishing the overlay private network consisting of the concerned members of the group related to the patient various parameters need to be considered.

Wireless networks require strong security mechanisms due to their open medium. However, security effects system performance, and therefore impact quality of services (QoS) of communications. To analyze the impact of security on system performance, [2] conduct a detailed experimental study on a wireless IP testbed with security at different layers. In our system the communication path with different QoS/Security levels can be established in an on demand basis considering following things:

- Network/Computational resource status
- Semantics of the transmitted data
- Role of the community members
- Health condition of the target person

to share necessary and sufficient information among specific members in the community, with ease and adequate safety and reliability.

At the same time, Peer-to-Peer (P2P) applications allow flexible organization, distribution of role to participating peers and the ability to share information with other peers for group collaborations. As a result, P2P systems are not only gaining importance, but also becoming ubiquitous media for information exchange. For trustworthy file sharing Abendroth et al. [3] proposed leveraging the trusted platform module. Advancement in sensor, information and communication technology can play an important role in achieving cost reduction and efficiency improvement in health-care delivery systems, to the extent that this offers high-quality medical service anytime and anywhere, compare to conventional health-care systems utilize a central server for the look up of information. But to use P2P system for handling patient's data, privacy and security are potential problems.

This paper is organized as follows. Section 2 presents Background of remote healthcare support system and overlay network. Related Works is introduced in Section 3. In Section 4 we discussed the System Description. System Architecture and Functional details is presented in Section 5. Finally this paper concludes in Section 6.

2 Background

Recent development of information technologies are leading the advent of the era of ubiquitous healthcare, which means healthcare services at any time and at any places. The ubiquitous healthcare service needs a wearable system for more continual measurement of biological signals of a user, which gives information of the user from wearable sensors.

Conventional health-care systems, including Mobihealth [4] project, utilize a central server for the look up of information. Traditional systems only focus on organic communication and service utilization between patient and hospital, whereas they ignore the systematic communication and sharing of information between health-care workers in the hospital and the patient's family members.

There are two main concerns for developing a ubiquitous health-care system. We have to keep privacy, which is a known barrier to the acceptance of ubiquitous computing technologies [5], for the patient's personal data and at the same time maintain the quality of the services in real-time.

We can assume an overlay network consists of patient and the related people, like the doctor, his/her family members, the physio and the neighbors. An overlay network is a virtual network of nodes and logical links that is built on top of an existing network with the propose to implement a network service that is not available in the existing network. For example, overlays can be used to increase routing robustness, to increase security, to reduce duplicate messages through multicast, and to provide new services for mobile users. They can also be incrementally deployed on the end hosts without cooperation from ISPs, and they do not need to deploy new equipment, or modify existing software/protocol [6, 7, 8].

This network can be built in an ad hoc mode depending on the necessity. The main difference between existing remote health-care system and our proposed system is that we are considering the level of privacy of each links according to the end-user and their relationship to the patient and the content of the data, the type of information it is carrying. We are also taking into consideration the condition of the patient, whether it is an emergency or a usual situation. The content of the information will also vary depending on that and so as the recipients. It is argued in [9] that anonymization and encryption may not provide perfect solution for privacy threats. So an overlay network has been considered here.

Although wearable computers have started to enter health-care delivery environments, wearable systems for both physicians and patients is not yet widely used. Wearable computers for physicians will allow them to treat patients and complete their round while connected via wireless networks to computerized patient records. Wearable computer are already allowing physicians to remotely observe patients' vital signs and monitor progress of surgery from outside the operating room using palm held devices. Medical sensors are now available for use by patients, ranging from conventional sensor based on pieze-electrical materials for pressure measurements to infrared sensor for body temperature estimation and optoelectronic sensor monitoring blood oxygen, heart rate, heart recovery ventilation, and blood pressure.

Recent convergence of ubiquitous computing and context-aware computing has seen a considerable rise in interest in various context-aware applications. These applications exploit various aspects of contextual environment to offer services, present information, tailor application behavior and trigger adaptation, based on the changing context.

Context information gathered from various sensor systems is the basis for enmeshing ubiquitous computing into our daily lives and exhibiting the autonomy of applications. Storing and acquiring such information into a single smart space can be easily handled by a centralized database server. However, handling large-scale context information over multiple smart spaces requires an appropriate context lookup architecture. Distributing database servers to multiple smart spaces in a wide-area network does provide a scalable and reliable solution. However, this approach requires a significant investment on servers, the bandwidth cost of storing updating context information, and administration restrictions. Emerging P2P approaches have been proposed to overcome some these obstacles, and providing potential solutions for large-scale distributed lookup system.

3 Related Works

In [10] et al. the authors' proposed an Open Healthcare Environment where multiple healthcare-related entities (such as patients, doctors, hospitals, and insurers) need to interact but do not necessarily have prior experience with each other. An open healthcare environment (OHE) means that a stranger may need to join a group collaboration where the entities are diverse and autonomous. It is important that OHE provides secure data sharing, access to data (or other resources), storage of data and transmission of data. An effective OHE will enable secure collaboration mechanism that permits (i) on demand formation of collaboration groups, (ii) the ability for qualified strangers to join a collaboration group, (iii) the ability to operate in a totally distributed setting without a central administration, and (iv) guarantees of privacy and security control by the users of the collaborative systems. AMON [11], a wearable medical monitoring and alert system targeting high-risk cardiac/respiratory patients. The usefulness of context aware services (CAS) within Personal Network (PN) is described in [12]. Where, CAS gathers context information about the user through sensor on the devices or information extraction from network/service elements. As this context describes all aspects of the owner's life, there is a fear to lose privacy. The authors argued that a PN can helps in dissolving this problem, as the context is only gathered, processed, and used within the PN. The PN will handle the security and privacy needs of the user. It will react to his movements around the world, maintain the connection between his personal devices based on con-

text information, and provide his context-aware personal services. The person himself can add new sensors as he/she wishes and install new context processing software that performs monitoring, logging and adaptation steps based on his context. For instance, he can install services that check on his health conditions, collect his movement of data, record them in a history database, and process them in order to identify situations. In somewhat similar way we can also use the concept of Overlay Network in our system. A system architecture of secure healthcare services based on Peer-to-Peer(P2) is proposed in [13]. This system consists of two regions: the Healthcare region and Hospital region. The healthcare Body Area Network (BAN) consists of sensors, wireless interface, PDA communication, and various facilities. The Hospital region composed of JXTA based P2P network that supports the doctor's mobility and dynamic service management modules. A policy based context aware overlay network concept is discussed in [14]. In this work they have described a policy layer composing a framework that assist in overlay management. The policy layer comprises a set of Policy Enforcement Points and a Policy Decision Point. The goal of this layer is to automate overlay network management. The behavior of the overlay network is adapted to the changing conditions in its environment. The creation, termination, and adaptation of overlays are achieved through policies. Policies are generated and enforced on the fly from the user, network and service provider context information. In ubiquitous computing environment, intelligent context-aware service should be adapted seamlessly to context-aware middleware. Semantic matching between service and middleware is needed for this. Ko et al. [15, 16] and Kang [17] talked about the importance of context-aware middleware and U-healthare and proposes a seamless service adaptation agent for context-aware middleware in wearable computing environment. To access ubiquitously present appliances anywhere and anytime through pervasive digital home environment Moon et al. [18] suggest the need of middleware that provides a high-level abstraction for zero-configuration and interoperability among middleware, makes each appliance's behavior context-aware, and supports a variety of adaptive behaviors. In this paper they proposed Universal Home Network Middleware, a context-aware and adaptive middleware for future pervasive digital home environment, that will provide a desirable environment that supports adaptability and dynamic composition through appropriate high-level abstraction.

4 System Description

The object target in our system is the person under observation, that is the patient or an elderly person who is in need for monitoring. The target person will be equipped with a wearable computer. They have been applied to areas such as behavioral monitoring, health monitoring system, information technologies and media development. Wearable computing facilitates a new form of human-computer interaction comprising a small body-worn computer (e.g. user-programmable device) that is always on and always ready and accessible. The always ready capability leads to a new form of synergy between human and computer, characterized by long-term adaptation through constancy of user-interface.

With a bluetooth device the patient will be connected to the ad hoc network. The other participants in the network will be the doctor, physio, family member(s) and the neighbors and they will have their own devices, like PCs or PDAs to monitor the related data including video images of the patient.

The general information of the patient can be broadcasted to all the person connected through the overlay network build on ad hoc basis. But there are sensitive data regarding patient's health (physical or mental) which should be handled with required care and the distribution of these data should reach only to the appropriate person(s). In order to transfer sensitive data between two entities data should be transferred through highly secure links and in high quality, as it may provide the required security [19]. The importance of security in healthcare support system at healthcare organization is discussed in detail in [21].

Overview of Community Private Network (CPN) is shown in Fig. 1 The upper most layer consists of four community members to manage health conditions of the Healtcare Target Person. They are his family member, doctor, health-care adviser and physiotherapist etc. The doctor, adviser and instructor make health-care advice based on personal profile, information and record of the target person stored in their individual local database.

Though the Community Private Network (CPN) is built to connect the members in uppler layer, its communication range will be limited within that small network unless we can use the Internet. So we need to consider about underlaying backbone of wired and wireless network. These members can be situated sparsely and far away from each other and at the same time changing their position dynamically. And there lies the bigger challenge, as nature and characteristics of the physical network layer and its topology, transmitting traffic is varying in nature and unpredictable. CPN should be constructed considering both the avail-

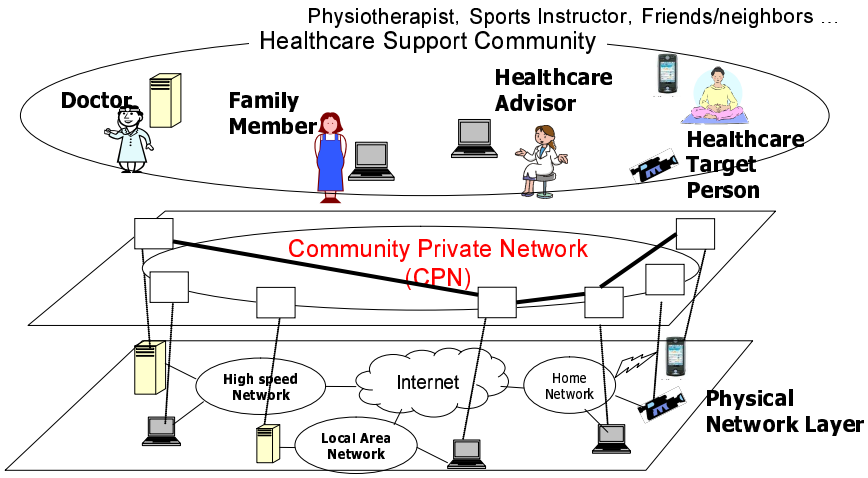

Figure 1: Overview of Community Private Network (CPN)

able resource and characteristics of the underlaying physical network and the requirement of the uppper layer. To achieve that we introduced a multiagent based layer in between CPN and Physical Layer.

4.1 System Scenario

Here we explain the scenario illustrated in the Fig. 2, where four community members to manage health conditions of the *Healthcare Target Person*, suppose Mr. X, by coordinating with his daughter, doctor, health-care adviser and instructor of the training gym. The doctor, adviser and instructor make healthcare advice to the target person based on the profile, information and record of him stored in their local DBs. His daughter has a laptop PC connected by wireless access link. The target person puts on a wrist-watch or any such wearable device sensor device connected to the PDA by Bluetooth. The PDA is also connected to the Internet with wireless access link. The vital data of Mr.X is transmitted to the Medical Record DB. In this case, high security communication path with encryption is automatically established between PDA and the DB as it contains private and sensitive data. If some abnormal symptoms are recognized on the vital data, the situation is informed to the health-care advice agent in the PDA. The agent collects useful information from health-care Web page. The agent subsequently provides the information to Mr.X. The adviser agent also requests to the Web camera to capture video image of Mr.X, because his condition may deteriorate. The live video is sent to both his family member and video DB. In this case a multicast path with high throughput and medium-level security is established to deliver the video streaming.

This kind of on-demand context-aware video delivery can greatly reduce network/computational resources, compared to 24-hours supervising, similar to our previous work [20].

5 System Architecture and Functional Details

Fig. 3 illustrated how the whole system is divided into four layers: *user layer, overlay network layer, agent layer* and at the bottom, the *physical layer*. Depending upon the user request, (here a secure path is required as vital personal data will be transferred), path will be established. The decision will be made at the agent layer, communicating with the physical network layer. In this example as the green path is inside a LAN, so it can be considered as secure, compare to the outside link, where security is a bigger concern.

On the other hand in Fig. 4 when live video streaming is transferred the quality of the video is more important that the security of the data.

The main features in this system are as follows:

1. Construction of an on-demand overlay network in ad hoc basis, including some or all of the members, depending on the situation or with user's choice.

2. The parameter needs to the considered:

   - Security of the links - when personal data will be transferred security is of highest concern.
   - Reliability - while transferring vital data reliability of (100% loss free) is very impor-

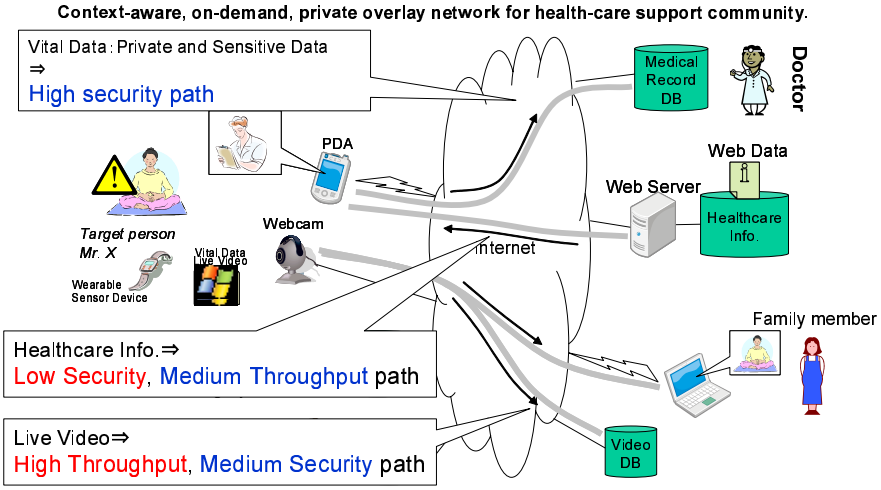

Figure 2: Transferring vital data with high security network

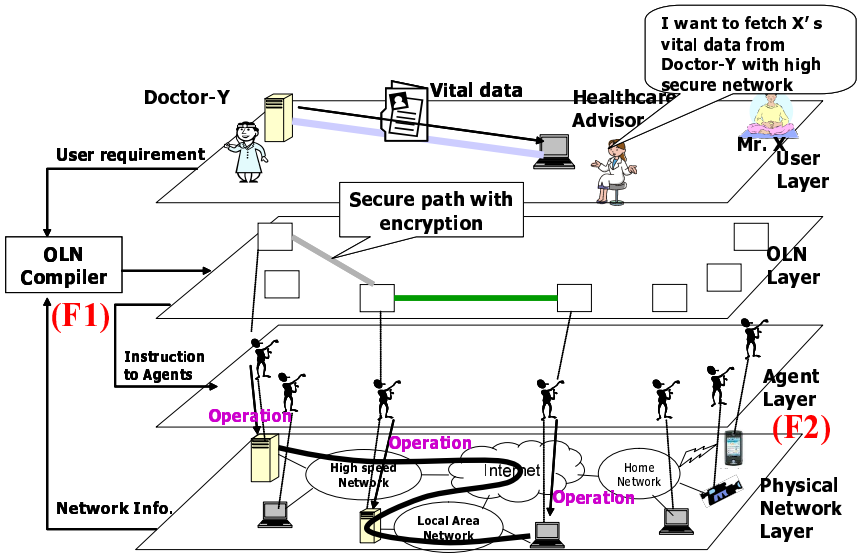

Figure 3: Transferring vital data with high security

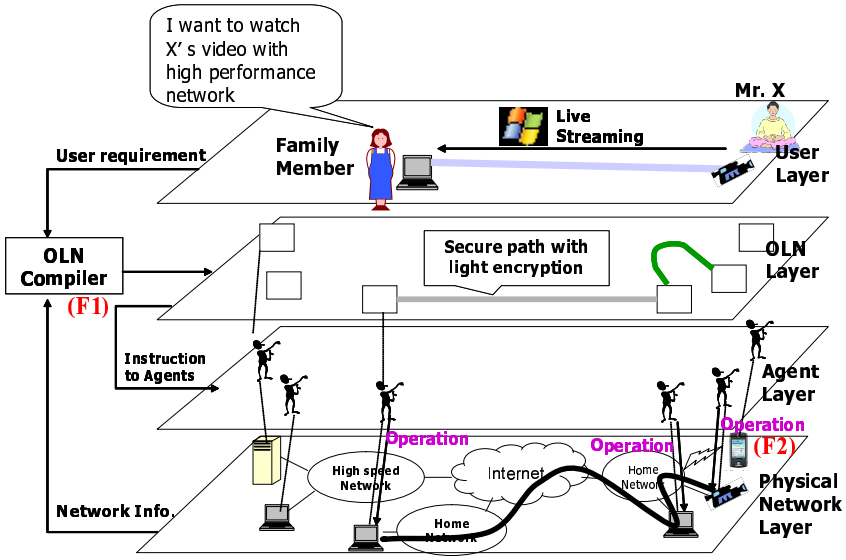

Figure 4: Transferring data with high video quality

tant. As incorrect data will incur inaccurate diagnosis.

- High performance - for the family members, who may prefer to watch the object person with live video streaming. Here, the quality of resolution is more important than security or loss free data transfer.
- Delay (jitter) - depending on the content of the information, such as, pulse rate or heart-beat, where the influence of jitter can play an important role and give an inaccurate picture of the actual situation.

3. Another important feature of this system is the establishment the overlay network in an ad hoc basis. Depending on the situation and necessity related members will be connected with each other with respective link-criteria (high QoS, high security, high reliability, low jitter etc.). We consider this ad hoc mode instead of 24-hrs monitoring and constant transferring of data, as keeping the system always active will be a sheer wastage of resource unless the situation is emergency.

The whole system can be divided in four layers according to the functionality as shown in Fig. 3 and Fig. 4.

(1) User layer - where all the members of this system exists, including the Target person, his/her health care support team, family members and friends/neighbor. In their respective display, whether it is a PC or PDA or any other devices, they can observe the image (or icon) of other entities. According to the situation or necessity they may want to connect to one or many members in that local community (consisting of the members). User can also mention the criteria of the connecting paths.

(2) Overlay Network Layer - This layer situated under the User Layer and receive the user requirement. The instruction will be conveyed to the next layer, i.e. Agent Layer.

(3) Agent Layer - Consists of agents with their respective role to serve their particular responsibilities to handle the devices in the actual network layer. This is a multi-agent platform, where negotiation among each other (agents) as well as with the network layer will play an important role to create the network to the satisfaction of user requirement.

(4) Physical Network Layer - In this layer the servers and all the other hardware devices exists. The upper layer's Agents will be responsible for these devices to establish a path as close as possible to the user requirement. This is a tricky task as it needs a fine balancing between user requirement and availability of resources.

5.1 Agent Architecture

The reason that agent and multiagent system have become increasingly relevant for distributed and dynamic intelligent environment is that they support wireless communication. This facilitates system portability to a wide range of mobile devices. Given mobile devices' low memory and processing resources, agents facilitate ubiquitous and transparent interactions and let developers personalize user ac-

cess. In addition agents have the following functionalities:

- agents are autonomous, reactive, proactive, social, logical and capable of learning [22].
- agents can act as an interface between the user and the intelligent environment's elements.
- can adapt to environmental changes or make predictions based on previous knowledge or experience making them capable of context sensitivity.

Agents are typically integrated into multiagent systems (MAS), or agent societies, exchanging information and resolving problems in distributed way. Such an organization facilitates ubiquitous communication and computation. To model problems, we must therefore achieve an organization-oriented perspective, identifying the roles that each agent plays with the society or system.

The basic architecture of agent is shown in Fig.5. Here Cooperation Mechanism (CM) is a mechanism for exchanging messages among agents. Domain Knowledge (DK) is a knowledge-base system to store and activate various domain knowledge concerning the target entity. Based on the knowledge, agent monitors and controls the target entity, and makes actions to other agents. Entity Processing Mechanism (EPM) is an interface between DK and target entity. It passes events from entity to DK such as exceptions, and directs control instruction from DK to entity.

DK consists of three subsystems, i.e., Working Memory, Inference Engine and Rule Base. In Working Memory and Rule Base, set of Facts and Rules are stored respectively. Inference Engine refers to the Rules and Facts, and works as production system. By employing this inference mechanism, agent performs interaction with other agents and controls the target entity.

An Agent-based Middleware for Ubiquitous Service Environment (AMUSE) [24], a multiagent system is considered for implementation. The basic idea of this framework is the agentification of all the entities in the ubiquitous computing environment. Here, Agentification is a process to make a target entity workable and context aware as an agent.

6 Conclusion

Well-being of the aging population is a big concern in many societies. Ubiquitous healthcare [23] is gaining interest as it can helps to overcome some of the critical problem regarding remote healthcare support. In this paper we proposed the concept of a secure and personalized health-care support system model. This system is comprised of various level of QoS and security in an on-line and on-demand fashion, considering the available computational power and bandwidth of the link, semantics of the transmitted data, relationship between the observed person and the recipient of the data, and the health condition of the concerned person. To provide such variety of characteristics we considered our system architecture based on overlay network, which is becoming widely used for delivering content in an effective and reliable manner that are not otherwise available [25]. A conceptual outline of this system is given in this paper and we are working on building a prototype system to evaluate it.

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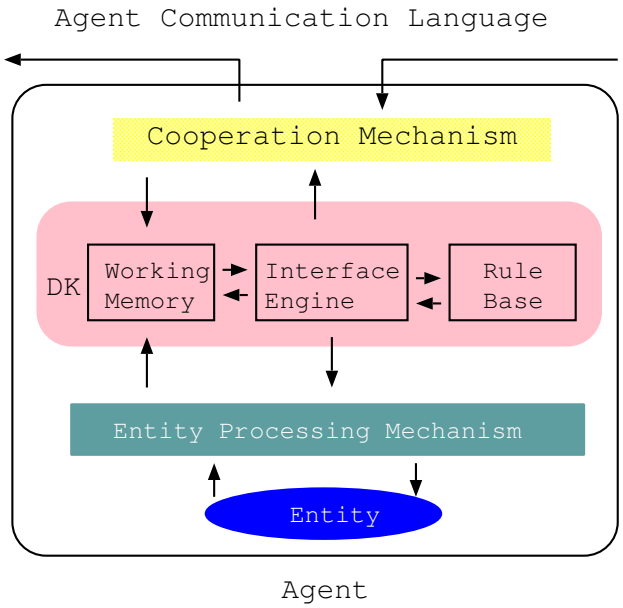

Figure 5: Basic Agent Architecture

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