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Multi Agents for Context Awareness in Ambient Intelligence: A Survey

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Abstract **: Ambient Intelligence (AmI) systems need the integration of innovative technology and complex environment for better solutions. In this sense, agents and multi-agent systems have characteristics such as reactivity, reasoning, pro-activity, autonomy, and social abilities which make them appropriate for developing distributed systems based on Ambient Intelligence. In addition, the utilization of context-aware technologies is an important aspect in these developments in order to perceive stimuli from the context and react to it autonomously. To the best of our knowledge a very small work has been done in Multi Agent based approaches for context awareness in Ambient Intelligence. In this paper some of the approaches were surveyed and lists of main requirements are identified for future research directions in this emerging domain. This paper discusses on the main objective and characteristics of the surveyed approaches and highlights the challenges to be addressed when designing and developing Multi Agent based approaches for context awareness in AmI.**

IndexTerms: **Multi Agents, Ambient Intelligence, Context Awareness, Mobile applications**

I. INTRODUCTION

Individuals are becoming increasingly accustomed to living with more and more technology in the hope of increasing their quality of life and facilitating their daily activities. The technological infrastructure to support human activities needs much work. Weiser [1] pointed out three main technology-related challenges that still had to be improved for effective service mechanisms for individuals (i) pervasive infrastructure with wireless communication and high bandwidth (ii) protocols to support mobility and heterogeneous devices (iii) development of standalone and network applications, aiming at data mobility over a network [1]. Nowadays, technology is advanced enough to allow such high expectations of [1], one such technology is Ambient Intelligence (AmI). AmI is a multidisciplinary approach that aims at the integration of actuators, sensors and communication technologies to create computer-mediated environments that support user activities through specific services of the environment, provisioned with minimal user intervention [2]. As such, AmI is the underlying technology necessary to support the integration of the entities that comprise an intelligent environment. This intelligent environment consists of a pervasive network of small electronic devices with minimum processing capability that act as either actuators or sensors to acquire information or act upon the environment, thus changing it. The implementation of AmI requires the support of tools and technologies such as middleware, frameworks and Multi agents. This technological consideration should be capable of collecting and interpreting large quantities of data collected from different sources [3]. The agent-oriented paradigm is particularly appropriate for implementing services to support AmI, because agents offer both functional and non-functional properties such as autonomy, reactive reasoning, proactive reasoning, learning and social abilities originated from the field of Artificial Intelligence that are vital in AmI applications [4]. This paradigm is also useful in modelling real-world and social systems. In these kinds of systems optimal solutions are not needed. Distributive environment problems in this paradigm are solved by communication and cooperation. AmI applications interact with each other in the form of a digital ecosystem of applications and services according to the accepted mobile standards, promoting interoperability and ease of expansion, which makes the development of such applications a very complex task. In recent years, various Multi Agent Based approaches have been proposed for AmI environment to reduce such complexity amd making easiness in designing. Multi Agent system plays a vital role in reducing such complexity in AmI applications.

In this paper we review and discuss different approaches of Multi Agent approaches for context awareness in Ambient Intelligence, and present some of the challenges. Thus in section 2, we provide some background information and related concepts. Multi Agent requirements are discussed in Section 3. In section 4, existing Multi Agent approaches are discussed. Section 5 provides a discussion of the Multi Agent challenges and section 6 concludes the paper.

II. BACKGROUND

Nowadays, there is a wide range of miniature, hand-held , portable and non-intrusive devices intended to help users with their daily life in [5]. The search for software capable of better adapting to people's needs and particular situations has led to the development of Ambient Intelligent (AmI) systems. AmI is a continuously evolving area, as new visions and theories appear,

towards more aware and user-centred systems. A large variety of disciplines can be considered under the umbrella of AmI : computer vision, data and information communication, distributed intelligence, ethics and law, information fusion , robotics, software and hardware design, social sciences, speech recognition [6]. AmI tries to adapt these technologies to people's needs by using Agents to incorporate omnipresent computing elements that communicate ubiquitously among themselves. M. Wooldridge in [7] defines an agent as a computational system situated in an environment and capable of acting autonomously in this environment to achieve its design goals. Expanding this definition, an agent is anything with the ability to perceive its environment through sensors, and to respond in the same environment through actuators. Further each agent may learn from the past experience and perceive its own actions in [8]. A multi-agent system is comprised of many interacting agents. Complex problems can be solved using Multi agent Systems, which are not possible for an individual agent. Thus a multi-agent system can be defined as any system composed of multiple autonomous agents capable of solving a comprehensive problem, where there is no global control system, the computing is asynchronous the and data is decentralized [7].

Clearly, these definitions are closely related to Ambient Intelligence. Tapia et al. [9], argues in favour of implementing multi-agent system (MAS) to build AmI-based systems, due to the autonomy, reasoning, reactivity, pro-activity and social abilities of agents. K. Sycara et al [10], suggests that there are several agent frameworks and platforms that provide a wide range of tools for developing distributed multi-agent systems. In [11], agents act as an essential component in the analysis of data from distributed sensors, gives those sensors the ability to work together, analyze difficult situations and obtaining effective communication with humans. Multi-agent systems have been successfully applied to several Ambient Intelligence scenarios, such as education[12], culture and entertainment[13], medicine [14], commerce [15], industry[16] and robotics [17]. Furthermore, J.M. Corchado et al.,[18] and B. Baruque et al.,[19] suggests that agents can use for reasoning mechanisms and methods in order to learn from past experiences and to adapt their behavior according to the context.

III. MULTI AGENT REQUIREMENTS

Multi Agent System (MAS) is a combination of various individual intelligent agents that work towards a common objective. These systems can be used to solve problems that are difficult or impossible for a monolithic or a single agent system to resolve. The usage of Multi Agent technology is becoming very popular in AmI applications because they can be seen as involving entities as autonomous agents that extract, process, change and share the available context information in [20]. MAS is necessary to support several functionalities in the AmI applications. These functionalities in different services might need to include both functional and non functional requirements in [21]. Lorena Rodriguez [22] identified the following major characteristics of multi agent systems:

1. *Adaptability*: this describes an agent's ability to modify its behaviour over time. In fact, the term "agent" is often taken to implicitly mean "intelligent agents", which combines traditional artificial intelligence techniques. It supports to perform task autonomously. It also supports the artificial intelligence sub-features such as sub-submission and learning.
2. *Collaboration*: collaboration among agents underpins the success of an operation or action in a timely manner. Collaboration with other agents can be achieved by sending and receiving messages. Agent communication language(ACL) supports collaboration among agents. High degree of collaboration leads to an effective distributive problem solving mechanisms among agents. Resource sharing in a distributive environment is type of collaboration among agents. In resource sharing collaboration, it is possible for agents to collaborate without actual communication.
3. *Disposition*: this refers to the agents' "attitude" towards other agents, and its willingness to cooperate with them. Agent might be of benevolent, self-interested or malevolent. Agents are said to benevolent, when it takes up a task based on request. Agent that harm or destroy other agents are termed as malevolent.
4. *Mobility*: this refers to the agents' capability of changing their execution between machines on a network. The manner of moving can be logical or physical. Logical Mobility refers to an agent running in a single machine that can be accessed globally using internet. When an agent travels between machines on a network, it is referred to as physical mobility.
5. *Pro-activeness*: this refers to how the agent reasons about the environment, reacts to its environment, and how it supports the user to pursue the goals. The agent can directly react to stimuli in its environment by mapping an input from its sensors directly to an action, or goal-oriented approach to achieve its goals or it can take a purely planning. Goal-oriented approach relies upon utilizing planning techniques.
6. *Veracity*: this refers to the agents' ability to deceive other agents via their messages or behaviour. An agent can thus be truthful in failing to intentionally deceive other players. Moreover, an agent that is untruthful may try to deceive other agents, either by providing false information or by acting in a misleading way.

In general, researchers propose Multi Agent based approaches best suited for their applications and environment. Based on the list of requirements, it is clear that the adhering to the

fundamental requirements is vital for any Multi Agent based Ambient Intelligence applications. Many applications may provide some of these requirements, but most of them do not support all the requirements of Multi Agent system.

IV. MULTIAGENT APPROACHES FOR CONTEXT AWARENESS

There is evidence in the literature that context-aware systems are a very active area of research in Ambient Intelligence in which multi-agent systems play a vital role [23]. Within this section, we focussed our survey attention on some multi-agent approaches that have been used in AmI. Each Multi Agent approach should have their own features, unique design, application domain and environment. Most of the approaches share some common characteristics as defined in Section 3. The following is a brief overview of the approaches we selected and Table 1 provides the gist of the approaches discussed.

A. AmbieAgents

The AmbieAgents infrastructure [24] is proposed as a scalable solution for mobile, context-aware information services. The Context Agent in this infrastructure manages the context information by considering privacy issues. They receive anonymized context information and execute queries in order to receive information that are relevant in the given context. Recommender Agent in this infrastructure uses ontologies and more advanced reasoning in order to perform more specific queries. The roles of agents are defined and their structure is fixed.

B. AmbieSense

The AmbieSense system has a multi-agent architecture for context-aware information services for mobile users that consists of wireless context tags, content provision platforms and mobile users in [25]. The goal of the AmbieSense project is to develop a platform that satisfies the information needs of travellers and mobile users by providing ambient and personalized information in a context-aware manner. AmbieSense system constitutes four agents. The first one, *Content Agent*, provides low level content. The next one, *Context Agent*, is responsible for interaction among the environment. The third one, *Recommender Agent*, uses reasoning mechanisms to deliver most appropriate content to the user. The last one, *Integration Agent*, acts as a wrapper agent that deals with interaction capabilities among ambient and non-ambient environment.

C. Agent Factory Micro Edition(AFME)

Agents with reduced memory and performance footprint for AmI have been developed in the Agent Factory Micro Edition project [26]. AFME is based on Agent Factory software agent. Agent Factory software agent is a type of pre existing fabrication framework in Foundation for Intelligent Physical Agents (FIPA). The authors succeeded in implementing a reliable communication. However, the communication between agents running in different devices is not possible. AFME infrastructure uses reasonably simple agents, however there is no higher level view that includes more complex global behaviour and there is no context-awareness.

D. CAMPUS

The CAMPUS framework [27] considers issues such as context, types of contexts and control mechanism. It uses separate layers for different parts of an AmI system. The layer *context provisioning* is closer to the hardware, it provides information on device location and resources. It also handles service discovery for services available at the current location. The next layer *communication and coordination* manages directory services, ACL messaging, semantic mediation, loading and unloading of agents, by using the Campus ontology. Another layer *ambient services* forms the upper layer to offer other services. The architecture is distributed. This system is having few centralized components, like the directory service and the ontology.

E. CARISMA

CARISMA [28] refers to Context-Aware Reflective middleware System for Mobile Applications. It is focused on mobile systems where they are extremely dynamic. Adaptation (also called reflection) is the main focus of CARISMA. Context is stored as application profiles (XML based), which allows each application to maintain meta-data under two categories: passive and active. The passive category defines actions that middleware would take when specific events occur using rules, such as shutting down if battery is low. However, conflicts could arise when two profiles defines rules that conflict each other. The active category allows relationships to be maintained between services used by the application, the policies, and context configurations. This information tells how to behave under different environmental and user conditions. A conflict resolution mechanism is also introduced in CARISMA based on macroeconomic techniques. An auction protocol is used to handle the resolution as they support greater degrees of heterogeneity over other alternatives. In simple terms, rules are used in auctions with different constraints imposed on the bidding by different agents (also called applications). Final decisions are made in order to maximise the social welfare among the agents.

F. CARMEN

CARMEN [29] is a middleware for resource management in context-aware systems. This system supports the context based automatic reconfiguration of Internet access in wireless environment. It has the ability to manage the resources even in unexpected disconnection. CARMEN uses proxies as mobile agents. This proxy is used by the user to access the resources in wireless environment. Responsibility of proxy includes the migration support across divergent environment with resource management.

G. CoBrA

CoBrA (Context Broker Architecture) is a broker centric agent architecture that provides knowledge sharing and context reasoning for smart spaces in [30]. It is specially focused on smart meeting places. CoBrA addresses two major issues: supporting resource-limited mobile computing devices and addressing concerns over user privacy. Context information is modelled using OWL ontologies.

Context broker is a server agent and it is the main element of CoBrA. A context broker comprises the following four functional components: context knowledge base (provides persistent storage for context information), context reasoning engine (performs reasoning over context information stored in storage), context acquisition module (retrieve context from context sources), and policy management module (manages policies, such as who has access to what data). Even though the architecture is centralised, several brokers can work together through a broker federation. Context knowledge is represented in Resource Description Framework (RDF) triples using Jena.

H. Cyberguide

Cyberguide [31] is one of the first systems to provide context-aware tour guide for mobile users. This system incorporates users' current location and history of past locations to provide the kind of services that are expected from a real tour guide. It presents a model and a multi-agent architecture called *SKELETONAGENT* based on deliberate approach to solve problems in web domains for web tourism through the integration of information gathering and planning techniques. *SKELETONAGENT* includes agents such as *UserAgent, WebAgent, PlannerAgent, ManagerAgent, CoachAgent and ExecutionAgent*. MAPWEB-ETOURISM, an e-toursim application has been developed to solve travellers problem.

I. iShopFloor

The iShopFloor [32] proposed reference architecture for implementation of distributed intelligence. The proposed reference architecture is intended for implementing Internet-enabled distributed manufacturing control systems in different kinds of shop floor situations, with particular attention toward lower volume, complex products/parts manufacturing. Such systems work in a dynamic world and keep pace with the changes in real time. The approach provides the framework for components of a complex control system to work together as a whole rather than as a disjoint set. *iShopFloor* system consists of three basic agents namely (i) *resource agent* to keep track of resources in the environment (ii) *product/part agent* to represent the details of the resources in the environment (iii) *service agent* to provide services to the requester and also to act as an communication agent between resource agent and service agent.

J. LAICA

LAICA refers to *Laboratory of Ambient Intelligence for a Friendly City* [33] . It brings good arguments for relying on agents in the implementation of AmI. The main aim of this project is to define innovative models and technologies for Ambient Intelligence in an urban context. LAICA addresses particularly with regard to security issues enabling AmI even at an enterprise level. LAICA deploys middleware architecture which is not distributed and this middleware is not agent oriented. Various autonomous individual components act as multi agents in this architecture. The two important agents in LAICA architecture are *sensor agent* and *effector agent*. *Sensor Agent* manages sensor devices in the environment and *Effector agent* hold the responsibility for actions in the environment. These agents are simple in nature. In LAICA, authors specifies an interesting idea of self organization agents, which specifies individual agents are not mandatory to be "intelligent", but the environment by means of collaboration, organization and coordination makes the system "intelligent".

K. LOQOMOTION

LOQOMOTION [34] is a mobile agent-based architecture for distributed processing of continuous location-dependent queries that are issued by mobile users, which allows the retrieval of objects' locations and other interesting data. LOQOMOTION process queries on static and dynamically moving objects with respect to their location, whereas other approaches only focus on queries about static objects that are in the vicinity of a certain static or moving object, objects moving within a fixed region, etc.,. LOQOMOTION is based on a layered hierarchy of mobile agents that move autonomously over the network. The goal of LOQOMOTION is to track the moving objects effectively, correlating the obtained data and finally presenting user with most relevant updated answer to their queries.

L. SIM

SIM (Sensor Information Management) [35] is focused on the smart home domain which addresses location tracking. SIM uses an agent based architecture according to the standard specifications provided in Foundation for Intelligent Physical Agents. SIM contains the following components in its architecture: *Agent Management System* to control the agents, *Directory facilitator* to maintain directory for agents and to hold services and descriptions of respective agents & *Agent Communication channel* to transfer messages in the environment. Its emphasis is on collecting sensor data from multiple sources and aggregating them together to analyse and derive more accurate information. SIM collects two types of information: node level and attribute level. In node level, node ID, location, and priority are collected. Attributes and their measurements are stored in attribute information base. A location tracking algorithm has been introduced using a mobile positioning device. A position manager handles tracking. SIM

has the capability to resolve conflicts in sensor information based on sensor priority. Conflict resolution is handled by a context manager with the help of aggregation, classification, and decision components. Even though SIM is not focused on hardware level context management, the approach is closer to low-level instead of high-level compared to other projects. This mechanism has proven to be extremely powerful and successful for managing and avoiding information conflict.

M. SpatialAgents platform

The SpatialAgents platform [36] employs mobile agents to offer functionality on the user's devices. Whenever a device used by a user which is also called an agent host, enters a location that receives certain services based on the location. Location Information Server (LIS) sends a mobile agent to execute on the device and offers the relevant requested services to the user. Agent mobility is monitored and frequently updated in the server. The architecture is scalable, but there is no orientation towards more advanced knowledge representation or context-awareness. The capabilities offered by mobile agents to the user make this system interesting.

N. X.MAS

uthors A. Addis et al., [37] proposes X.MAS as a generic multi agent architecture that is focused on information retrieval tasks that are aimed to retrieve data, filter data and restructuring data to provide information according to user's interests. It consists of the following categories of software agents: *Information agent*, customized to fetch and process information while accessing information sources; *Filter agents* to transform information according to user preferences; *Task agent* to offer ability to help users to perform tasks typically in cooperation with other agents; *Interface agent*, in charge of users interaction and *Middle agent*, acts as communication establishing agents among service requesters and service providers. The authors also present WIKI.MAS that classifies Wikipedia contents according to a predefined set of classes belonging to the WordNet domains.

O. Ao Dai

The Ao Dai refers to *Agent-Oriented Design for Ambient Intelligence* [38] studies in more detail the connection between agent hierarchy and context-awareness. The challenge in developing a MAS topology that remains decentralized and scalable is how to make the connections between agents related to their context. Another challenge is how to make the system context-aware to the dynamically changing context. The solution is based on two aspects: the use of the agent oriented programming language called *"ambient-calculus-inspired programming language"* CLAIM [39] and the definition of context-related relations and types of agents.

The idea of the Ao Dai architecture is to map the hierarchy of agents to a hierarchy of contexts, considering physical and computational contexts, as well as user's preferences. Ao Dai uses a hierarchical topology, where agents are placed in one or more trees of agents. Agents that are placed in hierarchies can be processed easily, CLAIM offers this easiness and it is very easy to move whole sub-hierarchies of agents in a topology. But Ao Dai constitutes agents such as *Place Agent* and *Service agent*. Here the context defined are inherently hierarchical. Social context and users' activity are not considered by Ao Dai.

P. EasyMeeting

EasyMeeting [30] is an agent-based system for the management of a "smart" meeting room. It is centralized, and it manages all devices in the room by means of reasoning on appropriate action. System design is based on the Context Broker Architecture (CoBrA) and uses the SOUPA ontology.

Q. MyCampus

MyCampus [12] is a mobile service based on semantic web and context awareness. MyCampus is comprised of *User Agent*,*Task Specific Agent* and *Info Agent*. In this system, authors specify an e-Wallet that stores information about the users. The components of e-wallet include platform manager and user interaction manager. This components offer authentication and directory services in a semi-centralized way. The e-Wallet learns the user's preferences and provides context-aware services to the users. Resources in e-Wallet are accessed and provided through web services. The services associated to agents are either public or semi-public (e.g. printers). Knowledge in e-wallet is represented using OWL. e-Wallet also manages issues related to privacy and security.

R. ASK-IT

The ASK-IT project [40] uses agents for the assistance of elderly and impaired persons. It uses the FIPA PTA (Personal Travel Assistance) architecture. ASK-IT contains many types of agents such as PErsonal wearable intelligent Device Agent (PEDA), Middle agent, Elderly and Disabled assistant agents (EDA), AmI service agent (AESA) and Personal Wearable communication Device Agents (PWDA). Each autonomous agent is specialized in environment configuration, information retrieval, service provision, user monitoring, etc. The structure and functions of ASK-IT agents are rigid. The feature of the system includes adaptation or flexibility to the environment.

S. DALICA

DALICA [41] is a multi-agent system that uses location data for the dissemination of information about cultural assets. The DALICA features a most interesting architecture, it is a combination of continuous Galileo positioning along with ontology and user profile. This system is capable of monitoring visitors and also monitors the transportation of said assets. DALICA is a part of European Cuspis project. The Cuspis MAS application consists of the application environment and

agents namely *generator agent*, *user profile agent* and *output agent*. The *generator agent* generates user profile when a user initiates a visit in the application. The *user profile agent* infers users' interests and monitors their behaviour. Finally, the *output agent* manages communication between user devices and infrastructures.

T. Fusion@

Fusion@ [42][43] relies on a decentralized architecture in which agents search for services to the users (SOA-based). Modular multi-agent architecture is implemented in Fusion@. In this architecture, applications and services are controlled by deliberative BDI(Belief, Desire,Intention) agents. Following are the different kinds of agents in Fusion@: *CommApp Agent, CommSer Agent, Admin Agent, Supervisor Agent, Directory Agent, Security Agent, and Interface Agent.* Each agent has specific roles, capabilities and characteristics. *CommApp* agent is responsible for communications between platforms and applications. *CommSer* agent is responsible for communication between services and platforms. List of services is managed by *Directory agent*. Supervisor Agent monitors the functionalities of other agents in the system. Security issues are taken care by the *Security Agent*. A special kind of low footprint agent called *Interface agents* resides on the users' mobile devices to avail services in the environment.

V. DISCUSSION

AmI has evolved due to the increasing possibilities offered by recent technological advancements. Context-aware system (CAS) is one of the domains of AmI systems. CAS is equipped with devices that recognize context and act accordingly to support the individuals. The main advantage of agent-based systems is the integrated features such as autonomous, reactive and proactive behaviour offered by agent paradigm and agent-oriented development tools. Another important advantage is the intelligence of the system. It means that the system and the entities composing it can learn and reason by themselves, without the need to program it for every specific task.In this survey we looked at several application areas of ambient intelligence, including the smart home, assisted living, industry, tourism and healthcare. In these, we looked broadly at features, role of agent, platform and challenges. The main objective is to know the different requirements covered by Multi Agent based approaches. At the end we found that none of them covers all requirements.

Our survey identifies that there is a natural association between AmI and MAS as identified by Tapia et al. [42] There is lot of challenges and complexity in designing AmI systems which can be effectively addressed by using Multi Agent systems. As we studied the different Multi Agent approaches for Ambient Intelligence, we find that

Table 1. Gist of various Multi Agent based approaches and their features.
(A- adaptability, C-collaboration, M- mobility, P- pro-activeness, V- veracity and D- disposition)

S.No	Approaches	Platform / Environment	Feature	Application Domain	Requirements Covered	Agent Structure	Context Awareness
1.	AmbieAgents (2005)	Mobile	Scalable	Context based information delivery	M,C,D	Fixed	Yes
2.	AmbieSense (2004)	Mobile	Augmenting digital information to physical objects	Travellers information	M,C,D	Fixed	Yes
3.	Agent Factory micro Edition (2006)	Mobile	Reduced Memory	Solution for memory footprint issues in Mobile	M	Fixed	No
4.	CAMPUS (2013)	Portable Devices	Configurable framework	Home Appliances	C,M,V	Fixed and Mobile	Yes
5.	CARISMA (2003)	Mobile	Dynamic , Adaptive	Smart Room , Conference Application	A,C,M	Distributed	Yes
6.	CARMEN (2003)	Mobile	Automatic Reconfiguration	Resource Management	A,C,M	Distributed	Yes
7.	CoBrA (2004)	Mobile	Supports resource limited mobile devices	Smart Spaces	M	Centralized	Yes
8.	Cyberguide (2005)	Web	First System to provide tour guide	TourGuide , e-tourism	D,C	Distributed	Yes
9.	iShopFloor (2005)	Web	a dynamic and keep pace with the changes in real time	Manufacturing Process and scheduling	A,C	Distributed	No
10.	LAICA (2005)	Web	service-oriented and multi-platform, and offers support for wide-spread applications in enterprise environments.	Traffic flow control	V,C	Not Distributed	Yes
11.	LOQOMOTION (2010)	Mobile	Dynamic in handling queries	Object tracking	M,P	Distributed	No
12.	SIM (2007)	Sensor Based	powerful and successful for managing and avoiding	Location Tracking system	C,M	Distributed	Yes

			information conflict				
13.	SpatialAgents (2004)	Mobile	Scalable	Location based Service	A,M,P	Centralized	No
14.	X.MAS (2008)	Web	Dynamic	Information Retrieval Tasks	V	Distributed	Yes
15.	Ao Dai (2011)	Mobile	Scalable , Decentralized	Spatial Services	C,M,V	Distributed	Yes
16.	EasyMeeting (2004)	Hand held and static devices	Ontology representation	Smart meeting room	A,C	Centralized	Yes
17.	MyCampus (2005)	Web and Mobile	Learns the user's preference	e-Wallet	D,M	Semi-Centralized	Yes
18.	ASK-IT (2006)	Mobile	Adaptation and flexibility	assistance of elderly and impaired persons	A,M,C	Rigid	Partial
19.	DALICA (2008)	Handheld PDA's and Web	Ontology representation, information dissemination	cultural assets	A,C,P,M	Centralized	Partial
20.	Fusion@ (2009,2010)	Mobile	Service-Oriented	Convergence of devices	M,C,D	Fixed	Yes

a well structured AmI application should be adaptive, intelligent, responsive, sensitive, transparent and ubiquitous. Adaptive, sensitive, and responsive are the features that support context-aware computing in AmI environment. Ubiquitous computing needs transparency and ubiquity for effective functioning in AmI environment. The intelligence of any AmI application helps in understanding users need in dynamic environments. This intelligence will consequently provide humans with adaptive assistance. Following are the other observations made through this survey : (i) many implementations for Ambient Intelligence do not rely on agents. (ii) agent-based systems for Ambient Intelligence do not explicitly use context-awareness. [40] (iii) some systems do not use agents as a distributed computing paradigm (iv) Agents are used in several projects on context-awareness, but there is no direct work on *interoperability* of context sources and consumers.[4] (v) Henricksen K and Indulska J [44] proposes the usage of rule-based reasoning to take context-aware decisions with several types of associations. (vi) Perttunen M et al. [45], addresses the modeling of context information using tuples, logical, ontological and case-based representations. While ontologies make an excellent tool of representing known concepts, context is many times just a set of associations that changes continuously. Dynamism in association leads to maintenance of ontology harder.

Our research findings suggest that, three main phases are to be considered in MAS AmI environment, towards the actual level of user-centeredness: (i) Social Value to the users (ii) inference mechanisms (iii) context-aware distributed systems. In other words, an effective Multi Agent based AmI should aim at achieving an effective machine assisted environment Weiser[1]. From the implementation point of view, developing such software and hardware systems is a challenging task. It requires adequate tools and procedures to adapt themselves and communication technologies. Based on the study of different approaches we identified the following concepts for effective commissioning of Multiagents in AmI environment:

(i) Environment with Embedded devices
   a. technology is ubiquitous and as indistinguishable from the surroundings as possible
   b. MAS approach for AmI environment should accommodate the existing divergent devices and forthcoming devices to suit the need of individuals. This system should also support the interoperability mechanisms among the heterogeneous devices. This interoperation increases the complexity of the systems. The work using web ontology languages indirectly supports a form of interoperability and custom reasoning.

(ii) Context-aware systems
   a. should obtain information and respond to the user as well to the devices in the environment.
   b. should support temporal, spatial and ongoing activities to infer the current context

(iii) Customizable systems
   a. users can establish a set of preferences that alter the system to their needs

(iv) Adaptive systems
   a. System should be capable of adapting to user and environment changes.

(v) Predictive systems
   a. capable of anticipating of users' wishes based on their past behaviour, incorporating either implicit or explicit feedback

In addition, temporal context, uncertainty, and privacy of the information must also be considered in designing Multi Agent based approach for context awareness. Hence, the effective design of MAS system should not compromise with the lack of any functional and non-functional requirements. Thus the design of MAS based on above features integrates knowledge from several areas and acts as an Intelligent Environment for AmI Applications.

VI. CONCLUSION

This paper reviewed on various Multi Agent approaches for Context Awareness in Ambient Intelligence and identified their general requirements. Designers, researchers and practitioners prefer to use the Multi Agent approach over the traditional approach because of its characteristics such as adaptability, collaboration, mobility, pro-activeness, veracity and disposition. This paper surveyed some of the application areas of Multi Agent approaches such as tour guide services to the travellers, data tracking and object tracking, Context based information delivery , Smart home domain, Smart Spaces, Manufacturing Process, Location based Services, ,Information Retrieval Tasks and solution for memory footprint issues in mobile devices. The approaches used in the above applications hold some similarities in the sense that all of them agree on a common goal: usage of multi agent. However, these approaches differ in their goal achievements. This paper also addressed the challenges to be considered in the design of a generic efficient Multi Agent approach for Context Awareness in AmI applications. In addition, Multi agent for context awareness needs to support efficient handling of the heterogeneous resources and functionalities of the Ambient environment. Due to the need to exchange enormous volume of data, it is necessary to have a scalable, reliable and efficient system to ensure uninterrupted flow information and messages. To enhance the role of AmI in user day-to-day activity, a dynamic, adaptive and autonomous Multi agent architecture design is to be considered.

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