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CONTEXT AWARE FRAMEWORK IN IOT: A SURVEY

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ABSTRACT

In the recent era of computing, Internet of Things (IoT) has evolved as a very constructive technology. Internet refers to dynamic and ever-evolving environments. It also generates contextual information which varies in terms of content, usability, quality and complexity. Day-by-day, the number of users are rapidly increasing, so that there is tremendous increase in users mobility and unreliable sensor availability in IoT. Hence, there is necessity to dynamically adapt their behavior at run time in the context-aware applications. In this paper, we have carried out survey of various approaches related to Context-aware systems and self-learning techniques in IoT. We have also focused on the need of different self-learning techniques to unravel the openness of IoT environment.

Key words : Context, Context-Awareness, Context Life Cycle, Internet of Things (IoT), Self-Learning.

1. INTRODUCTION

The term Internet of Things (IoT), coined by Ashton in 1999 [40], has been a growing technological trend in recent years. During the past decade, IoT has gained significant attention in academia and computing industry. IoT offers much more facilities as compared to other networking approaches like wired/wireless, LAN, Ethernet etc. hence it has become the main reason of research interest in current computing era. IoT promises a world where all the smart objects around us are connected to each other and spontaneously communicate with each other with the minimum human intervention. Ultimately the goal of IoT is to create a better world for the human beings. IoT is the new and emerging model in the computing which spontaneously links physical and virtual smart objects. IoT has high volume contextual information which enables context-aware smart applications. This virtual smart object provides real-time services, both cheaply and non-intrusively. The depravity and dynamicity of contextual data in IoT does not has guarantee about the traditional assumption of availability of the annotated training data prior to the classification for the classical machine learning algorithm which is used for context modeling, necessitating self-learning in the smart application.

In 1960s communication between two computers made possible through the computer network. In the early 1980s, TCP/IP stack was introduced and then commercial use of the internet get started in the late 1980s. Later In 1991, World Wide Web (WWW) was introduced which made internet popular and stimulated the rapid growth. WWW also includes the Web of Things (WoT), which is part of IoT. Later, various mobile devices connected to the internet and formed the mobile-internet. Then by social networking, users get connected to each other over the internet. The next big thing is the IoT, where object around us are able to connect with each other over the network and communicate with the help of Internet. Figure 1(a) and figure 1(b) shows the five phases in the evaluation of Internet and technology roadmap of Internet of Things (IoT) respectively.

IoT Application Domains: The application domain basically divided in to three categories based on their focus [24], [25]: society, industry and environment. Healthcare, home [28] and office, entertainment, ticketing, smart building, medical technology [29], telecommunication and media are some of the society focused applications of IoT. Some of the industry base applications are transportation and logistics [26], automotive, aerospace, aviation and supply chain management [27]. Disaster alerting, recycling, agriculture, breeding [30] [31] and environmental monitoring are some of the environment focused applications. There are some more applications which were described by Asin and Gascon [32] under twelve categories: smart environment, smart home, smart cities, smart water, smart meter, retail, logistics, industrial control, smart animal farming, smart agricultures, domestic and home automation, e-Health, security and emergencies.

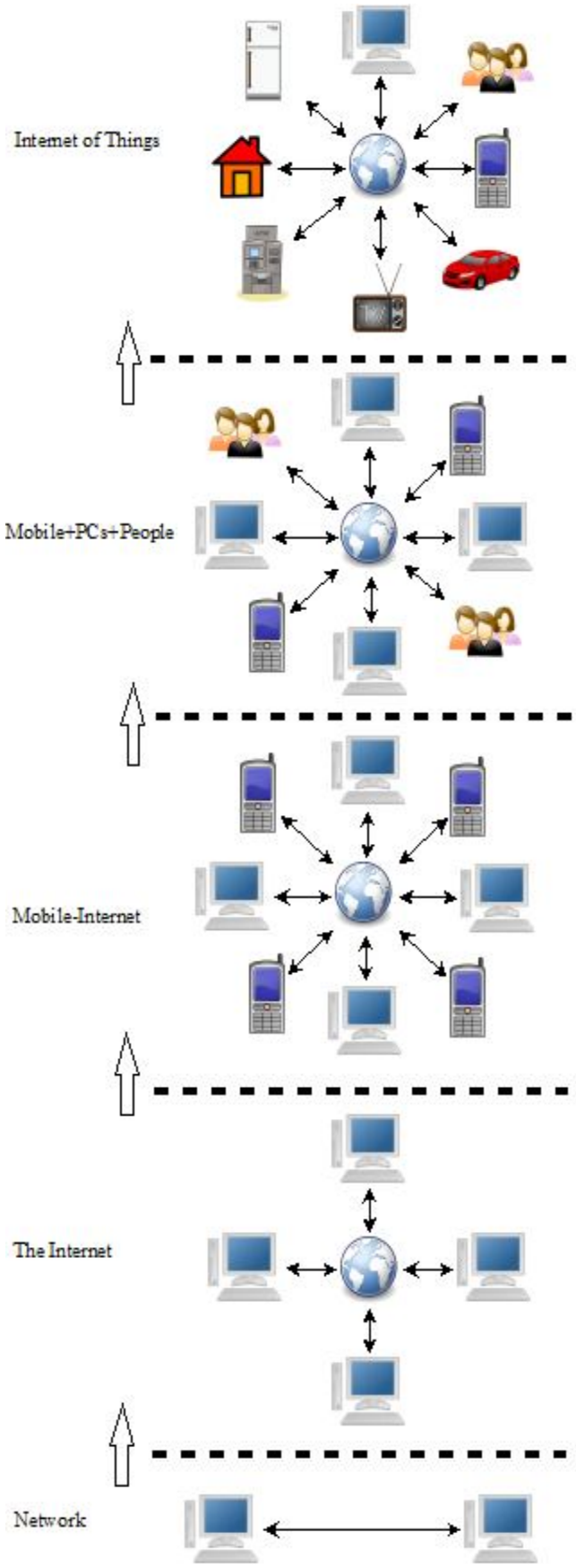

Figure 1(a): Evolution of the Internet in five Phases.

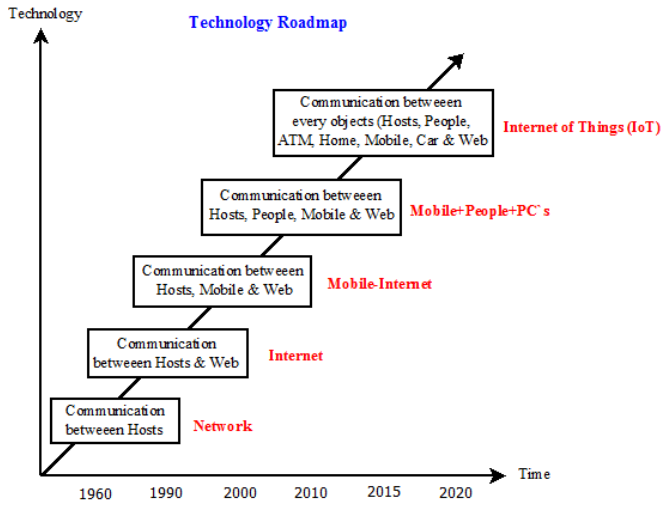

Figure 1(b): Technology roadmap of Internet of Things (IoT)

Context aware system is a core feature of pervasive and ubiquitous computing systems. From last decade, context aware system focuses from web applications, desktop computing to the Internet of Things (IoT). The term 'context-aware' was initially introduced by Schilit and Theimer [22] in 1994. Context has been defined by many researchers where as the definition of context provided by Abowed et al. [21] is *"Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves."*

Also, Sancherz et al. [23] explains the difference between raw data and context information as follows:

1) *Raw data:* It is defined as the unprocessed and retrieved directly from the data source, such as sensors.
2) *Context information:* It is defined as the generated data by processing raw data, checking for consistency and metadata, is added.

There was a period of beginning activity on Context-aware computing in late 1980`s. Nowadays, to overcome requirements and new challenges found in context-aware system and many researchers have done research on it. Due to advance sensor technology, sensors are getting stronger, cheaper and smaller in size. In today`s world we have a large number of sensors and ultimately this sensor generates large amount of data i.e. big data. Unless we analyze, interpret and understand the data we collected, that data may not generate valuable information. Context-aware computing played an important role in tackling this challenge such as mobile and pervasive, which would be successful in the IoT paradigm as well. Context-aware computing allows us to store the context information which linked to sensor data, so interpretation can be done more easily, meaningfully and also context makes it easier to perform machine-to-machine communication as it is core element in the IoT environment. Context-aware system

has been defined by many researchers where as the definition of context-aware provided by Abowed et al.[21] is *"A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task."*

A data life cycle shows how data moves phase to phase in software systems and specifies where data is generated and where data is consumed. Here we consider the movement of context in the context-aware systems. Hynes et al. [39] classified data life cycle in two categories i.e. Context Life Cycle and Enterprise Life Cycle. Enterprise Life Cycle focuses on context and Context Life Cycle focuses on context management. In addition to life cycles, C. Perera, et al. [2] identified four phases in a typical context management. Context life cycle consists of four phases as shown in following figure 2. In first phase, context needs to be acquired from the various sources for example virtual sensors or physical sensors: context acquisition. In second phase, the collected data is modeled and represented in meaningful manner: context modeling. Third phase need to process the given modeled data to derive high-level context information from low-level sensor data: context reasoning. In final phase, both the low-level and high-level context needs to be distributed to the consumers who are interested in context: context dissemination. So it is basically a cyclic yet dynamic process which provides required information to the users as per his demand.

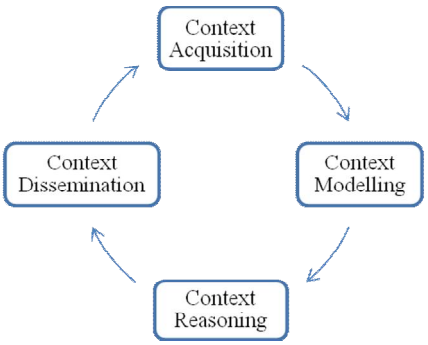

Figure 2: Context life cycle

Applications of context aware systems: Context-aware applications look at the who's, where's, when's and what's (that is, what the user is doing) of entities and use this information to determine why the situation is occurring. An application doesn't actually determines why a situation is occurring, but the designer of the application does. There are several applications as: Health care, Pervasive games, Smart phones, Proximate selection, Automatic contextual reconfiguration, Contextual information and commands, Context-triggered actions, etc.

There has been a wide literature available on context-aware computing. Chen and Kotz [33] had survey context-awareness and focused on several application and methodology used. In 2004, Strang and Linnhoff [34] compared the most popular context modeling techniques. Two separate surveys were conducted by Baldauf et al. [35] and Kjaer [36] in 2007 on context-aware systems and middleware solutions. Context representation and reasoning from a pervasive computing were survey by M. Perttunen, et al. [37] in 2009. In 2012, context-aware in mobile and wireless networking domain were surveyed by Makris, et al. [38]. In [2] C. Perera, et al. (2014) discussed a novel application of Context Awareness to analyse, compare and consolidate past research work from an IoT perspective.

There has been a wide literature available on context-aware computing from the year 1998-2014 focuses on several applications and methodologies, comparison of the most popular context modeling techniques, middleware solutions, context representation and reasoning from a pervasive computing, context-awareness in mobile and wireless networking domain and recently discussed a novel application of Context Awareness to analyse, compare and consolidate past research work from an IoT perspective [2],[33]-[38].

This paper is structured in four different Sections. Section 2 describes the survey of existing system in which we discusses the various survey papers and analysed it. Section 3 describes the comparative study of context-aware frameworks in which we compared all the previous papers, find out its methods which were previously used and come to some limitations. Finally in section 4, we conclude our literature survey and given future direction.

2. SURVEY OF EXISTING SYSTEM

In this paper we have divided the literature survey in to three major categories (Device-to-Device Communication, Self-Learning Framework and Application-oriented). The contributions of the researchers are summarized below:

2.1 Device-to-Device Communication

This categories again divided in to three sections i.e. past work, present work and future work as follows:

A. Past work:

R. Agrawal, et al. [9] discussed that, in a large databases of sales transactions there might exists problems for discovering the association rules between items. Hence author proposed two new algorithms over it, Apriori and AprioriTid These two algorithms can overcome the problems in the previously known algorithms (AIS [20] and SETM [19] algorithms). Finally author has shown the best features of two new proposed algorithms can be combined into a new hybrid algorithm, called AprioriHybrid algorithm. These AprioriHybrid algorithms have also some excellent properties in database with respect to the transaction size and number of items. Author need to focus on multiple taxonomies (is-a hierarchies) over items which are often available and they did not consider the quantities of the items bought in a transaction.

B. Present work:

D.G. Zhang, et al. [43] developed the new constructing approach for a weighted topology of WSNs based on local-world theory for the IOT. The definitions of vertex strength and edge weight take sensor energy, transmission distance, and flow into consideration. The vertex strengths improve the growth of topology; meanwhile, the changes are occurs in edge weights correspondingly. Experimentally author observed that the WSN topology that they obtained had the property of weighted networks of the IOT: the vertex degree, edge weight, and strength follow a power-law distribution. Also author shows that weighted WSNs not only share the fault tolerance and robustness of weight-free networks, but also reduce the probability that successive node breakdowns occur. Furthermore, they enhance the synchronization of WSNs.

C. Future work:

O. Bello, et al. [3] have surveyed, how intelligently Device-to-Device communication achieved in IoT environment. Authors discussed the overview of how intelligent D2D communication can be done in IoT ecosystem and they focused on how state-of-art routing algorithms can achieve intelligent D2D Communication in the IoT. They focuses the issue that impact intelligent D2D communication in the IoT environment also analyzed state-of-art communication mechanisms in licensed and unlicensed spectra and the classification of routing algorithm/protocol that supports intelligent D2D communications in the IoT. Authors did not fixed the issue of idle frequency. As we discussed that here two licensed and unlicensed spectra available and communication will be done based on the idle frequency, but if there are no idle frequencies, prospective D2D communication may not be carried out also if the allocated frequency utilized by the PU then D2D communication may be interrupted. Also author need to focuses on the routing discovery and management, cooperation between devices in IoT, security, integrity and authentication.

E. Khorov, et al. [4] had discussed the overview of an novel Wi-Fi technology aim to organize communication between various devices used in applications like: smart home, smart city, smart grid, smart environment, smart healthcare systems, smart industry, etc. Author addresses the activities of TGah, its challenges and the key mechanism of the upcoming IEEE 802.11ah standard. Also they discussed the set of use cases considered by TGah, their relevance to smart systems and problems to be solved in .11ah. Authors also discussed an overview of the PHY layer needed in MAC and solutions to address all problems related to challenges of smart city implementation. Authors did not fixed the issue that the given decision making algorithms is out of the scope, saying what to do but not when or how to do.

2.2 Self-Learning Framework

A. Past work:

J. Hong, et al. [10] have suggested a new classification framework of context-aware systems and explored each feature of classification framework which were developed based on the architecture of context-aware systems, having five layers: user infrastructure layer, application layer, middleware layer, network layer and concept and research layer. Authors reviewed the literatures for the concept and applications and examine them using dimensions related to ongoing and emerging issue in context-aware system. Frameworks offer a general development guideline, fundamental concepts and relationships between components of context-aware systems. Author did not fixed the issue i.e. some relevant articles might have been overlooked. White paper, many articles related to context-aware not reviewed the correlation between the framework and real projects are not illustrated. Though they did not mention how to extract & use of cognitive context and what design patterns of context-aware system used.

B. Present work:

D. Preuveneers, et al. [6] had discussion on a loosely coupled Bayesian-based learning framework to improve the readability by allowing dynamic many-to-many relations between context sources and smart applications. On one hand, the framework exhibits flexibility to dynamically add and remove the contexts through automatic learning of individual contexts relating to distributed ubiquitous infrastructures. On the other hand, it incorporates the advantages of multi-view learning by fusing multiple heterogeneous context information streams. Author developed an Heterarchical, Autonomic, Recursive and Distributed Bayesian Network (HARD-BN) to improve the performance of the framework, its adaptability and flexibility for adding and removing context information. Authors did not fixed the mitigation effects of view disagreements between individual Bayesian networks also need to extend the framework by considering Quality-of-Context (QoC). QoC parameters like reliability and timeliness as they are crucial in combining diverse context.

C. Future work:

A. Ramakrishnana, et al. [1] discussed the self-learning in the dynamic and open IoT environments. Author has described what is Internet of Things, self-learning techniques to tackle the openness of IoT ecosystem and proposed correlation mining algorithm to achieve them. This algorithms help to identify the alternate sources for the context and this proposed algorithm is on top of a Bayesian framework (HARD-BN) which supports autonomous learning. Also authors have discussed the state-of-art machine learning modeling techniques, a loosely coupled Bayesian framework for the

context-aware applications and automation correlation mining between user contexts to discover the frequent set mining for hierarchy. They mainly discussed the two algorithms i.e. proposed Apriori frequent set mining algorithm and KL divergence based correlation mining algorithm for the self-learning in the dynamic and open IoT. Author need to focus on Applicability of these algorithm to various use cases for statistically verifying their usefulness and scalability. Also, need to explore meta-learning prospective and how it will be helpful for life-long learning in open and connected environment of the future.

C. Perera, et al. [2] carried out a survey on the context-aware systems, tried to make clear definitions of context, context-awareness, and context-aware system from IoT perspectives. Author addressed a broad range of techniques, models, methods, functionalities, middleware solutions, systems and applications related to context awareness and IoT to analyse, compare and consolidate the previous research work. They discussed the detailed about what is context, context awareness, context-aware system, Internet of Things (IoT) and context life cycle. Also they discussed when was these terms discovered and by whom and how IoT was came from the internet (see figure 2). Here, author analysed and evaluated context-aware computing research efforts to understand how the challenges in this field have been tackle in desktop, web, and sensor network, mobile and pervasive computing paradigms. Still author has not touched the facet of *context discovery*. There are many types of context to access the sensor data in the wide range of IoT, so it is a challenging task to discover the required context. Context *acquisition, modelling, reasoning and distribution*: After analysing these four in different perspectives, it is clear that no single technique would serve the requirements of the IoT. Integrating multiple techniques can succeed in the field of IoT but due to immaturity in the field of IoT, it is challenging task to predict when and where to employ each technique.

2.3 Application-oriented

A. Past work:

C. M. Olsson, et al., [42] discussed about the context-awareness, context-aware applications and interactional context view for designing context-aware applications. Author develop and test design principles for context-aware applications that convey an interactional view of context. They discussed that, recognising of the car is not an excellent thing but also to provide the monitoring system and handling the car`s behaviour dynamically and use of context-awareness application in that is also an important.

B. Present work:

S. Bhattacharyya, et al. [11] discussed the requirement of health care application and based on that they developed a health care application by using the context-aware system. Author developed a controlling, monitoring and reporting health care system for the patients. They specifically focused on the brain tumour. They discussed, how to gather data from the patients by using various physical wearable devices (sensors) which were used by the patients and send that all information/context to given monitoring system and give notification/reporting to the care person so as to avoid any accident. Authors built an ontology starting from knowledge gathering of data and reasoning to identify the health condition of the patient. So this has led to move towards to build an abstract framework for context-aware applications. Authors need to focus on system that should allow caregivers to use sensors to assist with daily health and monitoring tasks and provide early warning using sensor data collection.

C. Future work:

J. Moon, et al. [41] propose dynamic context-aware user interface framework for the second screen devices in home network environment. Also authors discussed an architecture of the framework and they simulated dynamic adaptive user interface for second device with IPTV service. Authors proposed SADL implemented with MPEF-21 DID and they simulate the framework that can access static and dynamic contexts in real home network environment such as IPTV services through UPnP protocol.

R. Ribeiro, et al. [5] discussed a fuzzy information fusion algorithm which is based on multi-criteria decision making. They proposed an algorithm for data/information fusion, which also includes the concepts from multi-criteria decision-making and computational intelligence, specifically, fuzzy multi-criteria decision-making. The application area of interest for this work is safe spacecraft landing with hazard avoidance; hence author used two existing hazard maps to illustrate the versatility of the proposed algorithm. Author did not distinguish the fusion process from the decision making process.

3. COMPARATIVE ANALYSIS OF CONTEXT-AWARE SYSTEM

Following table 1 shows the comparative analysis of context-aware system.

Table 1: Comparative Analysis of Context-Aware System

No	Paper Title	Paper Details	Methodology	Limitations
1	Enabling self-learni-ng in dynamic and open IoT environme-nts	Arun kishore Ramakrishnana, Davy Preuveneersa, Yolande Berbersa, ScienceDirect (Elsevier), 2014	• IoT • Self learning • Correlation mining • Apriori frequent set mining • Bayesian Network	• Need to focus on Applicabilit-y of these algorithm • Meta-learni-ng prospective • Life-long learning

2	Context Aware Computin-g for The Internet of Things: A Survey	Charith Perera, Arkady Zaslavsky, Peter Christen, and Dimitrios Georgakopoulos, *IEEE Explorer*, 2014	• Context, Context awareness, Context-aware system, IoT, Context life cycle, etc. from an IoT perspective • Analysis, compared and consolidate past research work.	• Context discovery • Acquisition • Modeling • Reasoning and • Distribution
3	Intelligent Device-to-Device Commun-ication in the Internet of Things	Oladayo Bello, And Sherali Zeadally, *IEEE SYTEMS JOURNAL*, 2014	• Intelligent D2D communica t-ion achieved in the IoT ecosystem. • Presents licensed and unlicensed spectra • Classificati on of routing algorithm/ protocols	• Energy efficiency • Idle frequency • Rout discovery • Authenticat -ion • Security
4	A survey on IEEE 802.11ah: An enabling networkin-g technolog-y for smart cities	E. Khorov, Andrey Lakhov, Alexander Krotov, Andrey Guschin, *ScienceDirect (Elsevier)*, 2014	• Overview of key mechanism of a novel Wi-Fi technology in the draft standard IEEE 802.11ah • Addresses the activities of TGah, its challenges • Use cases by TGah • Overview of PHY laye-r needed in MAC	• Given decision making algorithms out of the scope, saying what to do • But not when or how to do
5	FIF: A fuzzy informatio-n fusion algorithm based on multi-crite-ria decision making	Rita A. Ribeiro, Antonio Falcao, Andre Mora, Jose M. Fonseca, *ScienceDirect (Elsevier)*, 2014	• Propose an algorithm for data/inform-ation fusion • Includes concepts multi-criteri-a decision-making & • Computational intelligence	• Do not distinguish the fusion process from the decision making process
6	A loosely coupled & distributed Bayesian Framewor-k for multi-cont-ext recognitio-n in dynamic ubiquitous environme-nt	Arun Ramakrishnan, Davy Preuveneers and Yolande Berbers, *IEEE Explorer*, 2013	• Present a loosely coupled Bayesian-ba-sed learning frameworks • HARD-BN	• Need to extend framework by focus on Quality-of-Context (QoC) parameters such as timeliness and reliability
7	Context Aware Health Care Applicatio-n	Shankari Bhattacharya, RA.K Saravanaguru, and Arunkumar Thangavelu, *IJICT*, April 2011	• Discussed the requiremen t of health care application • Based on that they developed an health care application by using the context-awa-re system	• System should allow caregivers to use sensors to assist with daily health and monitoring tasks and • Provide early warning using sensor data collection.
8	Context-aware systems: A literature review and classificati-on	Jong-yi Hong, Eui-ho Suh, Sung-Jin Kim, Science *Direct (Elsevier)*, 2009	• Review previous works • Suggest a new classificatio-n framework of context-awa-re systems • Five layer architecture	• Not mention How to extract & use of cognitive context • What design patterns of context-awa-re system? • Correlation between the framework and real projects are not illustrated
9	Fast Algorithm for Mining Associatio-n Rule	Rakesh Agrawal, Ramakrishnan Srikant, *Proceeding*	• Proposed two new algorithms Apriori and AprioriTid	• Need to focus on multiple taxonomies • Did not

		of the 20th VLDB conference Santaigo, Chile, 1994.	• AprioriHyb-rid algorithm	consider the quantities of the items bought in a transaction
10	A new constructi-ng approach for a weighted topology of wireless sensor networks based on local-worl-d theory for the Internet of Things (IOT)	De-gan Zhang, Ya-nan Zhu, Chen-peng Zhao, Wen-bo Dai, Science *Direct (Elsevier)*, 2012	• New approach for a weighted topology of WSNs based on local-world theory for the IOT • Vertex strength and edge weight	• Did not discussed about the wired technology.

4. CONCLUSION AND FUTURE DIRECTIONS

We have carried out literature survey of various factors associated with Context-aware systems. We discussed what IoT is, how it comes from the internet and its applications in our lives. Also we have seen what Context is, context-awareness and context aware system applications. We have gone through the context life cycle which include four phases i.e. context acquisition, context modelling, context reasoning and context dissemination. And finally we have done critical analysis of various techniques and their limitations.

There are many future research directions in the context-aware systems. Areas like context discovery, acquisition, modelling, and reasoning, and distribution, selection of sensors in sensing-as-a-service model, security, privacy, trust and context sharing are considered as primary unexplored areas.

- *Context discovery:* There are many types of context that can be used to enrich sensor data. Understanding sensor data and appropriately annotating it automatically in the IoT, where application domains vary widely, is a challenging task. Recent development in linked data and semantic technologies shows future direction.
- *Acquisition, modelling, reasoning and distribution:* Due to immaturity of IoT, it is difficult to predict when and where to employ each technique. It is important to define and follow standard specification so different techniques can be added to the solutions without significant effort.
- *Selection of sensors in sensing-as-a-service model*: Quality frameworks need to be defined and employed.
- *Security, privacy and trust:* Security and privacy need to be protected in several layers. Acceptance of users in most important in IoT. Therefore, security and privacy protection requirements need to be carefully addressed in order to win the trust of the users.
- *Context sharing*: Sharing context information between different kinds of middleware solutions and different instances of the same middleware solution is important.
- *Context reasoning*: For context reasoning level requirement of developing efficient algorithms using unsupervised learning, ANN based approaches.
- *Uncertainty management*: development of new uncertainty management models using Hidden Markov Model (HMM) to capture the uncertainty aspect in this context-aware framework.

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