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Implementing a Reliable and Context-Aware Framework in Pervasive Computing for Event Reporting by Using Intelligent Technique

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Abstract

The Appearance of new generation of computer systems, embedded systems, mobile, and also advances in mobile wireless networks, cause to extension of the computation fields. This process, lead to a scenario which is called: "pervasive computing". The aim of pervasive computing is the presence of computers in all fields of the human life, without the need to his presence, coordinating among all computer systems which related to each other and also the reduction of the calculations complexity. As the computations being pervasive, the nature of the requests be changed. The requests awareness of context is one of the most important features in pervasive computing, Because being aware of the context enable system to make automatic decisions. Context including any information about the person or object, such as location, identity, surrounding objects, feelings, environmental conditions and etc. For ease of planning requests, Context is collected, managed, and then finally a general conclusion had be done. pervasive computing include three major subsystems, Sensing subsystem, thinking subsystem, and the Acting subsystem. In this paper, by using the context, a reliable and context-aware framework for pervasive computing is presented which we called it, intelligent pervasive computing system. This system can evaluate received data from environment optimally by using machine learning technique.

Keywords: Pervasive Computing, Context, Context-aware, Artificial intelligence, Reliability.

I. Introduction

At the beginning computer systems were mono core and worked in serial, but need to high computational speed, led the processors to parallelism. With the advent of pipeline technique, the serial operations divided to some independent micro-operations that can be run in parallel, so each of these micro-operations will run along with other micro-operations that are running in other parts. With introducing the SMT (Simultaneous Multi Threading) technique, speed increases in mono core processors, and this trend had a better evolution with the advent of multicore and multi processors [17,20]. So the computer systems that were initially Mainframe, due to increasing performance and utility, were pushed to the computer network. But not only with connecting computers as the network processing power could increase, but also another concept with name of distributed systems is used. Types of distributed systems are such as wireless sensor networks, Grid networks and pervasive computing. Distributed systems, is a collection of independent computers, so that from the user perspective, are supposed as a unified and coherent system[5,12,19,20].

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Technological advances open up their way in all areas of human life. These improvements is affected the way of shopping, interact with others, moving from one place to another, and other aspects of human life. In fact, our life goes fast towards pervasive computing. With pervasive computing, computers are pushed to the background and placed those in their surroundings, so while they are fully accessible and usable, they are hidden from people view. To achieve this purpose, the computer should be turned into smaller computational tools and placed on furniture, walls, and buildings [23]. For communicating with the external environment, we require two sets of devices called sensors and actuators. Sensors receive the environment quantity and give us the digital values, and Actuators are applying our processing results to the environment [12].

With mobile computing, computer networks, and wireless communications, the importance of pervasive computing also increase. Pervasive computing will change drastically the way we think about the environment because changes many immovable objects and abiotic entities of environment to seeable and hearable entities that can interact with their users [23]. The aim of pervasive computing is the presence of computers in all fields of the human life, without the need to his presence, coordinating among all computer systems which related to each other and also the reduction of the calculations complexity. Context- awareness is of features that apart a pervasive system from non-pervasive system, because Context-Awareness will cause the system to be automated and optimized in decisions making. Context includes any information about the person or object, such as location, identity, surrounding objects, feelings, environmental conditions etc. For ease of planning requests, Context is collected, managed, and then finally a general conclusion could be done [2, 12, 23].

Pervasive computing is formed from the three major subsystems [12,6], a Sensing subsystem, a Thinking subsystem, and an Acting subsystem that discussed in section 4 of this paper. In section 5, using artificial intelligence and machine learning techniques, we provide a reliable, safe, and context-aware framework in pervasive computing that system form a more optimal decision on data received from the environment. In section 6, the advantages, disadvantages and challenges of pervasive computing will be discussed. In section 7, some applications of pervasive computing have introduced and finally we conclude the paper in section 8.

2. Foundations of Research

In this section, first introduce pervasive computing and then major components of systems based on the pervasive computing discussed.

1.2 Introduction to pervasive computing

Emergence of new types of embedded computer equipment, mobiles and advances in wireless networks caused developments in various aspects of human life. This means that the tasks used by the computer system be done by embedded systems. This process led to a scenario named pervasive computing [5]. Pervasive computing termed by Mark Weiser [5,24], the theorist of pervasive computing, in 1990. For pervasive computing, a lot of different names are suggested in [12] mentioned, and we'll introduce some of these names:

- ***Ubiquitous Computing***

this theory was introduced by Mark Weiser in 1991 and refers to the use of power of all computers, as it is hidden from view.

• ***Pervasive Computing***

This topic first introduced by the director of IBM, Lou Gerstner and point out the instruments, sensors, and computers that are spread around us. Pervasive computing, in reality is the combination of mobile computing and embedded computers in constant environments.

• ***Invisible Computing***

invisible computing consists of using computers in any way for convenience and doing jobs without need of special tools.

• ***Disappearing Computing***

Disappeared calculations is combination of specific hardware and software that with interact with each other and combining their abilities form a new behavior.

• ***Proactive Computing***

the focus of this topic is not on interaction with user but supports users' needs. With this, user with less interaction with the computer will focus on higher level jobs.

• ***Autonomic Computing***

Autonomic computing has very large overlap with the Proactive Computing and with combining them we end up with ubiquitous computing.

• ***Ambient Intelligent***

This field provides user convenience based on ubiquitous computing and with making an intelligent user interface for access efficient services.

• ***Sentient Computing***

Sentient Computing, using various sensors and data sources, drawing a model of the peripheral world to be able to share it between applications and users. Many systems do this, but for their compatibility with each other, there is a need for a global model and synchronization with pervasive computing.

2.2 objectives of pervasive computing systems

Pervasive Computing systems are designed with different objectives. The first goal of the design of these systems is providing Context-Aware or sensitive to context systems. The second objective of these systems is to facilitate the presence of computers in all fields of human life without human presence, coordination among all relevant computer systems, and also reducing the computational complexity. The third objective of the design of these systems is handling of the possible events. And fourth objective of these systems is the use of heterogeneous materials [12.2].

3.2 Context and the contextual conditions

The idea of the context is derived from many fields, including linguistics, physiology, problem solving in the field of artificial intelligence, communication theory, etc. In fact, the context, is the main key to our thinking [5,7]. Contextual conditions have been expressed with this definition: something on our side that gives meaning to something else. Context can include information such as location of people and objects, time, state of program executions, computing resources,

bandwidth, activity, intention, user feelings (Picard, 1997) and environmental conditions (Dey, 2001) [12] .

4.2 Context-aware pervasive computing

Schilit et al in 1994 are described the context in mobile and distributed computing as: the context is information that is directly in person's environment. This information can include the location, identity of persons, objects around, user feelings, environmental conditions and so on. Dey in 2001, described context for the new computing as: Context, including any information that can personify the position of an entity. Entity can be a person, place, or an object. The important thing here is that, the context collected by the data that achieved by sensors [10,12,23].

5.2 Context-aware system

A context-aware combination of hardware and software that could automatically update itself and react according to the background. context-awareness, it making active the system for automated decisions and reduces user involvement with the program. Context, specified depending on the application and conditions [12,23].

6.2 Characteristics of Contextual Information

Contextual Information is divided into two categories: static and dynamic. Static contexts are static text data such as date of birth, while the dynamic contexts are variable data and are usually the majority of the data [5]. In the following, Some of the disadvantages and problems [5], which may threaten the pervasive environment, has stated:

1. Incomplete contextual information because of a delay in updating the old and new information.
2. Misinformation generated by users or machines or sensors.
3. Space exists between the information produced by the sensors and the information used by the software.

To solve these problems, various solutions come to mind, including the existence of several alternative forms of the same context.

7.2 Bayesian Decision Theory

Bayesian theory, is one of the artificial intelligence and machine learning techniques that the its framework based on probability theory, and is used for decision making in places or situations in which there is no certainty. As future may be somewhat similar to the past in some degree, so future could be predicted partly from the events happened in the past, but this is not always true. Bayesian theory can be expressed as the following formula [1]:

$$P(C|x) = \frac{P(C)P(x|C)}{P(x)} \quad (1)$$

3. Artificial Intelligence and Machine Learning

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Before the creation of electronic science, artificial intelligence was coined by mathematicians such as Boole. Artificial intelligence was coined in 1965 as a new science. The term artificial intelligence, termed the first time by John McCarthy. The main goal of machine learning is that a machine or computer gradually with increasing the data, find higher yields in the desired task. Scope of this task could be face recognition, speech recognition, plate recognition for traffic control, control of agricultural environments, learning style step for robots with receiving reward and punishment signals, and so on. Spectrum of researches in machine learning is widespread. Researchers want to create new learning methods and applying machine learning methods on new issues. Machine learning, includes two stages of train and test. Each machine is first trained and after getting enough training, could be tested. We have decided to take the help of the concepts of artificial intelligence and machine learning, to provide a reliable and safe model in pervasive computing[1,16].

Machine learning techniques divided to four categories of Supervised Learning, Unsupervised Learning, Semi-supervised Learning and Reinforcement Learning, which in the following we described these techniques [1].

1.3 Supervised Learning

In this type of learning, both input and output are specified, and output is labeled. Supervised Learning, need some input data for the educating system, and in fact, a supervisor learns to the system which input linked to which output. Supervised Learning is divided to the two categories of classification and regression. Figure 1 shows an example of classification indicates that the samples are labeled and the sample class is determined, and goal is to find discriminant function to separate the different classes. Problems in which the output is in the form of number are called Regression Problems [1].

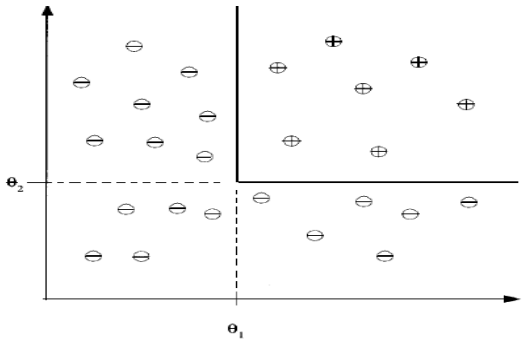

Figure. 1. Example of classification, the samples are initially labeled[1].

2.3 Reinforcement Learning

This type of learning does not provide any type of input and output, but here the primary goal is with using of Fine and Reward. In this type of learning, if the learner agent, do good work reward is granted to him and if the learning agent commits an error the fine granted to him. Rewards and Fines often are shown with scalar values such as -1 and +1[1].

3.3 Unsupervised Learning

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In two previous types of training the system is linked input to output, but sometimes, we want the system relate what see or hear to the type that has already seen without knowing that what is seen. In this type of learning, no supervisor exists and the goal is not relating or linking input to output but the target is clustering of prototypes. This learning is important because, in the real world, system is facing with some unlabeled input. There are many algorithms for unsupervised learning and one of most important is K-means algorithm [1].

1.3.3 K-means algorithm

1 - The main idea in this algorithm is defining k center, and k is the number of clusters, so the center of each cluster is unique. These centers should be selected very carefully, because different centers, have different results. Best selection, is placement of centers, in most possible distance from each other another.

2 – In the next step, the distance of all points to all k-defined centers defined, calculated and every point assigned to the nearest center. When all points were allocated to existing centers, first stage completed and an initial clustering is performed.

3 - After the initial clustering, at this stage, there is a need to identify new centers for the clusters. New center in each cluster, obtained with calculating the average of all samples of the same cluster. After determining the new k center, then every point, allocated to the nearest appropriate center.

4 - Repeat these steps until centers have not moved, or so-called, centers converge. This process is shown in Algorithm 1 [1].

Initialize $m_i=1,\ldots,k$, for example, to k random x^t Repeat
For all $x^t \in X$

$$b_i^t \leftarrow \begin{cases} 1 & \text{if } \| x^t - m_i \| = \min_j \| x^t - m_j \| \\ 0 & \text{otherwise} \end{cases}$$

For all $m_i=1,\ldots,k$
$m_i \leftarrow \sum b_i^t x^t / \sum_t b_i^t$
until m_i converge

Algorithm.1. Clustering algorithm K-means [1].

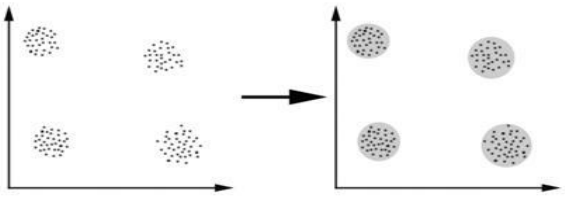

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Figure. 2. An example of clustering on the set of data by using distance between data criterion [1].

4.3 Semi-supervised Learning

This type of learning is the combination of labeled and unlabeled prototype, or in other words, the combination of supervised and unsupervised learning. System is faced with many samples during the day. In this case, the system can be spontaneously made decision and use supervisor's experiences when the supervisor is present too[1].

4.The main elements of pervasive computing systems

For a better understanding of the context-oriented pervasive computing systems, we follow the following scenario: We understand the environment, with the five senses: sight, hearing, taste, smell and touch. Our brain with processing our feelings about environment, conclude and will be forced us to react. Our reactions may be very immediate (such as muscle contraction, etc.), and/or after careful and long planning. Given the above scenario, a context-oriented pervasive computing system, constitute from three major subsystems, named Sensing Subsystem, Thinking subsystem, and Acting subsystem. This process is shown in Figure 3 [6,12].

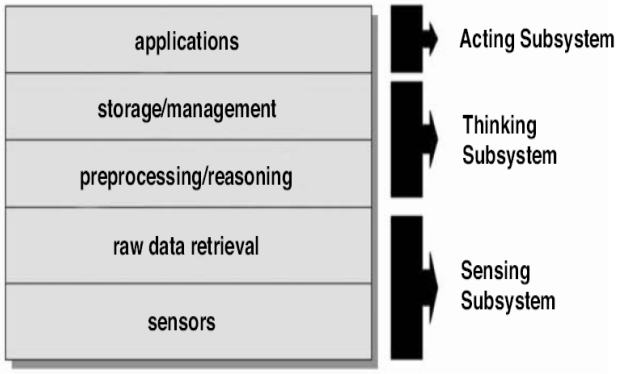

Figure. 3. Elements of a pervasive computing system in base of context-awareness[6].

1. 4 Sensing Subsystem

As shown in Figure 3 sensing subsystem, which is the lowest pervasive computing subsystem, consists of hardware sensors, and these sensors have unique characteristics such as being energy dependent [12]. Sensors were first used in military applications, but over time they applications expanded. Sensor networks are a set of small sensors that are working together for information gathering [21]. Sensors, in fact, are part of pervasive computing systems and based on context conditions, to collect environment data [13]. In the higher layers of this subsystem, raw data retrieval layer, information that are collected by sensors, decrease as much as possible and most efficient information received from the environment are maintained [6,12].

2.4 Thinking subsystem

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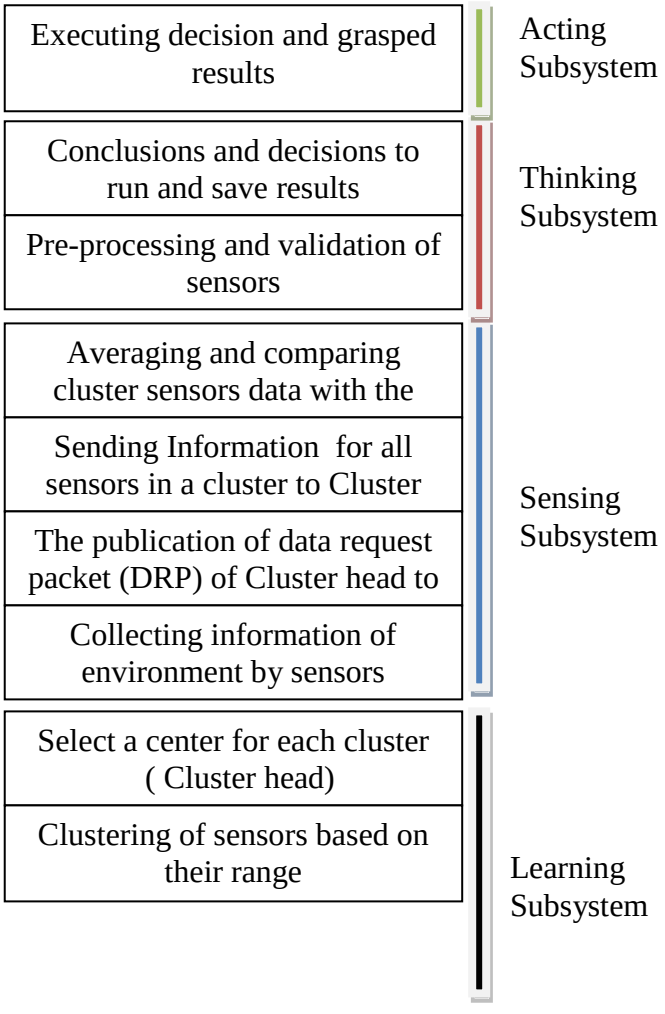
Valid data collected in sensing subsystem, finally transferred to the Thinking subsystem. tasks of this middle subsystem are pervasive computing, reasoning based on past experiences and understanding of current conditions [12]. In this subsystem who is most important subsystem, according to collected information decision will be made with help of traditional decision making, artificial intelligence, Bayesian decision theory, clustering, Markov model, fuzzy logic and etc. After a proper decision, somehow should previous experience increased and result to be stored. Finally, the results would transfer to the Acting subsystem.

3.4 Acting subsystem

This subsystem is the highest subsystem of pervasive computing and is responsible for executing decision made by thinking subsystem. At this stage, according to a specific application, and place that will utilize this system, the activity must be performed. This field, according to the type of application, is very widespread and numerous software and hardware actuator designed for it and many are not designed [12].

5. Provide a comprehensive framework for pervasive computing based on intelligence techniques



Ordering the sensors in environment based on Bayesian

Figure. 4. The proposed framework for pervasive computing based on intelligent techniques.

After introducing the components of pervasive environments, we have now tried to apply the techniques of artificial intelligence and machine learning on the pervasive environments and provide an intelligent, reliable, and safe model in pervasive computing, so the information collected by the sensors best deduce the context.

The key questions here are ones that can be mentioned in the following:
- What is the most optimal way of setting and embedding sensors in the environment?
- What is the best method of collecting environmental information by sensors?
- What is the most reliable method of data transmission of sensors to actuators?
- How we deduce the context from the sensor data?

Context-Awareness helps systems in the optimal and automated decisions. In fact, any information obtained from the sensors, could be effective for creating a context. Context includes any information about the person or object, such as location, identity, surrounding objects, emotions, environment conditions, sensible modes of user, etc. [12].

Since the aim is increasing reliability and security of the pervasive system, for achieve this goal it is necessary to there be Redundancy in the system. the idea of our proposed model has been taken of [22,15,1] and will follow the following algorithm:

1- The use of Bayesian Theory, allow us to predict future events according to past. These predictions, resulted to embed most of the sensors in places that are looked more events in the past. These, in part, help the system to achieve the optimum solution. Figure 5 figure this out.

2- In a grid with large number of sensors, probably several sensors, received simultaneously and similarly environmental data so it is preferred that the volume of data are somewhat reduced before thinking and acting subsystems.

3- A simple and effective design is use of clustering algorithms and divide workspace to grid cells. Probably the sensors within a grid cell sometimes received invalid or duplicated information so reducing duplicate and invalid information, greatly increase efficiency, and helps to reduce path traffic. Choosing smaller grid cells, greatly increases the accuracy, while a larger grid cells, will be reduced data less and optimize network performance, so the size of the grid cells must be balanced, optimized, and the selected regarding to range of sensors.

4- According to Figure 6, in all grid cells, a unique node called the cluster head is selected and is responsible for the Cluster management. This node in each cell is responsible many tasks such as collecting data of its grid cell sensors, making the average between the data, compared information of all of grid cell sensors with a mean value of that sensor and also distinguish valid and invalid sensors.

5- Security in distributed systems could be reviewed in two backgrounds: security in sending data and security in data content. Till now very solutions are presented including encryption, for securing the content and sending data. The solution that we propose is highly effective in improving security.

6- The proposed solution in the correct sending of data is thus: Cluster head that is unique in each cell, propagate data request packet (DRP) to all sensors within its cells. All sensors inside the cells that received data request packet (DPR), send a package named data send packet (DSP) to their cell's cluster head according to figure 9. After sending data of all sensors of a cell to cluster head of that cell, decision will be made between all packets and then packets that its volume of source and cluster head sensors data are not equal, regarded as incomplete and invalid data. This process is shown in Fig 10.

7- The proposed solution for the health of content of receiving information is thus: Cluster head, in each cell, after collecting valid data of its grid cell sensors making the average between all these data. The Cluster head is responsible for comparing information for all available sensors in a cell, with mean value of same cell, which in its result, sensors that their information are very different with mean considered invalid. Necessarily much difference between received data from the sensors with the average calculated by the Cluster head, not means sensor failures. The Cluster head is responsible for comparing information of each cell with adjacent cells information.

8- We moreover to Cluster head nodes, define another nodes as the Reporting Node. Cluster head also can be reporting node. Reporting Nodes of R1 and R2, as shown in Figure 6 have the task of collecting and classifying data and information of their environment grid cell data, so that information collected together and send to higher subsystem of pervasive computing or thinking subsystem to decision be made about those data. These nodes also greatly reduce the path traffic. Selecting two reporting nodes of the R1 and R2, greatly help reliable system, because, in case of failure of one node, another node, would collects information on all cells.

9- After collecting data in all the sensors of reporting nodes, this data should be transferring to thinking subsystem. In thinking subsystem based on information collected, thinking and reasoning is performed according to data and field would be prepared for traditional decision-making algorithms, artificial intelligence and machine learning. After a proper decision, somehow previous experience must be increased and result stored. Finally, the results will be sent to the Acting subsystem. Sending information can be done based on different algorithms such as shortest path. Also, the use of a backup path, to transmit information to thinking and acting subsystems, greatly helps the system to be reliable. This process is shown in Figure 7.

10- Finally, conclusions and decisions, transferred to the acting subsystem and by the Actuators are implemented. If there are several Actuators, the results will transfer to the nearest Actuator. This process is shown in Figure 8.

11- Important to mention here is that in the event of some event with different priorities in the environment, the priority is to run more important events, but for events with the same priority, the priority queue is used.

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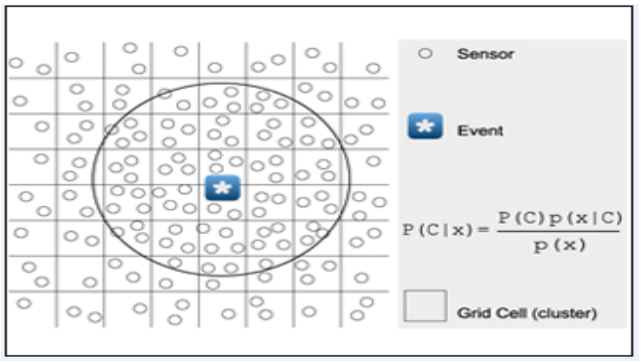

Figure. 5. Setting the sensors in the environment based on the Bayesian Theory.

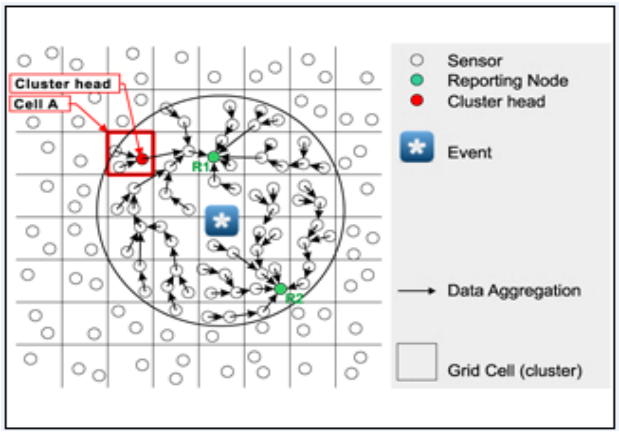

Figure. 6. Divide workspace to grid cells for collecting events by the sensors.

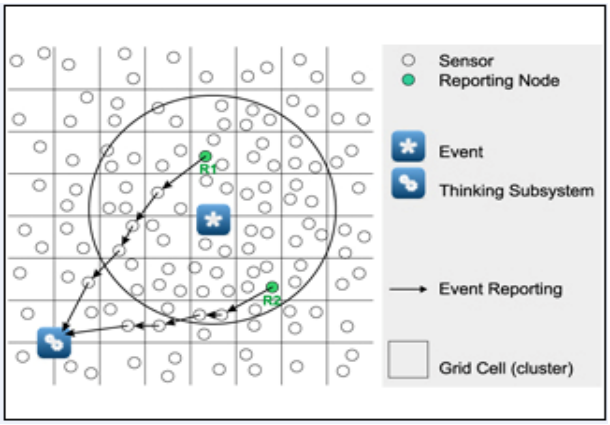

Figure. 7. Information transfer from reporting nodes to the thinking subsystem.

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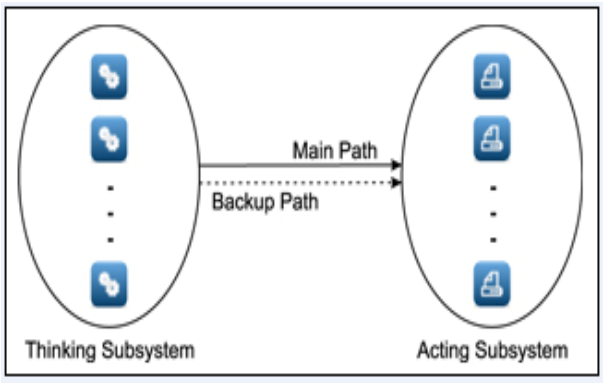

Figure. 8. Transfer of result to acting subsystem and executing of results.

Volume of sending packet in sensor	Data collected by sensor

Figure. 9. Data sending Packet that all sensors within a cluster, send to their own cell Cluster head.

Volume of sending packet in source sensor	Data collected by sensor	Volume of received packet in destination sensor

Figure. 20. Verify data validity in the Cluster head.

6. Analyze the advantages, disadvantages, challenges and threats of mobile and pervasive computing applications

1.6 The benefits of pervasive environments

We can mention the following the main advantages of pervasive computing:

- Capability of wireless communication between ubiquitous and invisible devices.
- Ease of use of computer and Internet for users.
- The possibility of mobile commerce.
- Increase the speed of computing through a combination of several devices.
- Lower cost of infrastructure and convenient Internet connection.
- Movability.

- Effective use of smart space.
- Interactive effect of user and pervasive environment on each other.

Perhaps the major advantage of the pervasive environments comparing to non-pervasive environment is context-awareness of them. Context-awareness, could change applications and natures and increase requests. So pervasive environments, are very more flexible, more independent and are automated [4,12,18,23].

2.6 Disadvantages of Pervasive environments

Naturally pervasive environments, have their disadvantages too. Some of the major disadvantages of pervasive environments are as follows:

- Low-life batteries for mobile devices.
- Limited bandwidth due to the use of devices such as GPS, which have low accuracy.
- Bad user interface.
- Displaying inappropriate web pages on small communication devices.
- Limited flash memory.
- The limited processing power.
- The problem of coverage in blind areas.
- Negative social effects.
- Reduce the security and privacy of users, because of Hackers and facilitated governments by getting user's private information, such as living place of users [4,14,18,23].

3.6 Pervasive environment challenges

Transition from traditional systems into a pervasive system, is of the most important challenges that threaten the pervasive environment, because for pervasive system hardware must be changed. Leaps toward miniaturization of computer components at the atomic scale, or nanotechnology, considered the most important challenges in pervasive environments. Worries of users of the observation of their data in the wireless space, is another challenges of this field [4,14,23].

7. Applications of pervasive computing

Today pervasive computing has found a wide range of application as a framework in different spheres of life, including agriculture for air and soil moisture control, speech recognition, face detection, control and record vehicle speeds, reduce accidents and traffic, smart homes, industry, digital libraries, control of shopping in stores, etc. [5,8,11,24].

The project Aware-home is trying to build a house that understand its residents and helps them [13]. Pervasive healthcare project in Canada provide pervasive services to help patients in and out of hospital to physician and patient demands performed intelligently with minimal direct intervention of people [9]. Also, the scope of pervasive computing is such that its role has been suggested in the sport environments [3].

8. Conclusions

One of the main advantages of a pervasive system comparing to non-pervasive system is context-awareness, unlike the non-pervasive system, pervasive system make decision according to user needs and the environment and
all the underlying conditions, because the context-awareness, help the system in making automated and optimized decisions. Use of artificial intelligence and machine learning algorithms can dramatically improve the collecting and managing of information in pervasive computing layers.

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