Circuits and Systems, 2016, 7, 3212-3227
Published Online August 2016 in SciRes. http://www.scirp.org/journal/cs
http://dx.doi.org/10.4236/cs.2016.710274

Enabling Resource Awareness in Integrated Sensor Grid Framework Using Cross Layer Scheduling Mechanism

Sottallu Janakiram Subhashini[1], Periya Karappan Alli[2]

[1]Department of Computer Science and Engineering, KLN College of Information Technology, Anna University, Tamilnadu, India
[2]Department of Computer Science and Engineering, Velammal College of Engineering & Technology, Anna University, Tamilnadu, India
Email: subhashinisj@yahoo.co.in

Received 10 March 2016; accepted 1 April 2016; published 24 August 2016

Abstract

Researches related to wireless sensor networks primarily concentrate on Routing, Location Services, Data Aggregation and Energy Calculation Methods. Due to the heterogeneity of sensor networks using the web architecture, cross layer mechanism can be implemented for integrating multiple resources. Framework for Sensor Web using the cross layer scheduling mechanisms in the grid environment is proposed in this paper. The resource discovery and the energy efficient data aggregation schemes are used to improvise the effective utilization capability in the Sensor Web. To collaborate with multiple resources environment, the grid computing concept is integrated with sensor web. Resource discovery and the scheduling schemes in the grid architecture are organized using the medium access control protocol. The various cross layer metrics proposed are Memory Awareness, Task Awareness and Energy Awareness. Based on these metrics, the parameters-Node Waiting Status, Used CPU Status, Average System Utilization, Average Utilization per Cluster, Cluster Usage per Hour and Node Energy Status are determined for the integrated heterogeneous WSN with sensor web in Grid Environment. From the comparative analysis, it is shown that sensor grid architecture with middleware framework has better resource awareness than the normal sensor network architectures.

Keywords

Cross Layer Scheduling, Data Aggregation, Energy Conservation, Heterogeneity, Middleware, Sensor Grid, Sensor Web, WSN Framework

How to cite this paper: Subhashini, S.J. and Alli, P.K. (2016) Enabling Resource Awareness in Integrated Sensor Grid Framework Using Cross Layer Scheduling Mechanism. *Circuits and Systems*, **7**, 3212-3227.
http://dx.doi.org/10.4236/cs.2016.710274

1. Introduction

With the introduction of Micro Electro Mechanical Systems (MEMS) [1], various progresses take place in the size reduction of the electronic circuits and thereby integrating multiple applications in a single chip. A small wireless sensor device can incorporate various types of sensors, processors, memory and wireless transceivers. Such devices can be termed as Network on Chip or simply Sensor Network. Another major developing domain is Grid Computing which is basically the networking of various heterogeneous computation strategies. Users and applications can share their resources by enabling the Middleware architecture using grid computing. So grid computing can be termed as "computing on tap" or "on-demand computing". Combining the features of Sensor Networks and Grid Computing institutes an innovative architecture called as "Sensor Grid" [2]. Sensor Grid establishes a single integrated platform for exploring the salient features and characteristics of sensor networks and grid computing. The same is illustrated in **Figure 1**. In the sensor grid arrangement, the heterogeneous sensor networks are connected globally using the multi level protocol and domain architectures. The individual sensor nodes in the sensor group communicate within themselves by means of cluster head. This is known as Intra Cluster communication. Each cluster communicates to the other cluster either directly via, Inter Cluster Communication or through the globally available sensor. The former communication is suitable for homogeneous sensor group whereas the later one is preferred for heterogeneous sensor group. In such global sensor web, the cluster heads of each cluster communicate with the sensor grid by means of Grid Resource Services and Grid Resource Brokers. The applications and the protocols matching the communication between the heterogeneous sensor groups are facilitated to the Grid Resource Services through the Grid Resource Brokers. The control communication channels are established by command-action messages and sense-actuate messages.

The immense development in the high definition video transmission in the global web architecture has stipulated the next generation wireless frameworks. In the epoch of Information and Communication Technology (ICT), the high quality and standardized data communication is the need of the hour. Data speed in terms of Gbps is proposed in the Next Generation Networks (NGN). Various heterogeneous applications Wireless Personal Area Networks, Wireless Sensor Networks and Long Term Evolution devices can be integrated in the web based platform using the grid architecture. The communication between these multiple standards shall be

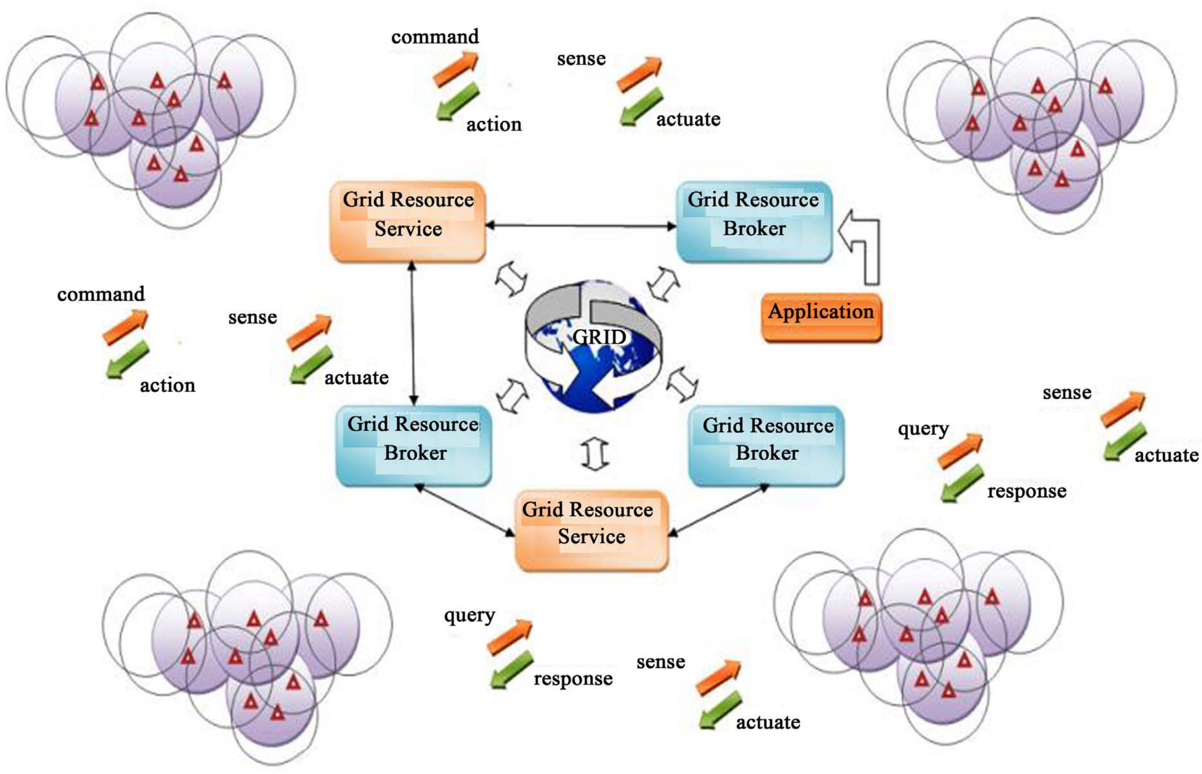

Figure 1. Sensor grid integrating sensor networks and grid computing.

established through the internet cloud or through middleware frameworks. For this, Wireless Sensor Network over Web (WSNoW) can be established as the platform. The key resource areas in this sensor grid architecture are the awareness of various resources like memory, task and energy. Also, the integration of heterogeneous applications, cross layer scheduling mechanisms are to be established in the middleware framework among the high tier, medium tier and the low tier protocols. Sensor web platform can be used for such integration.

The main objective of the proposed work is to design a middleware architectural framework using the cross layer scheduling with resource discovery and energy conservation in the Sensor Grid. For analyzing the various cross layer metrics such as Memory Awareness, Task Awareness and Energy Awareness, optimal scheduling algorithms are implemented in the cross layer of WSNoW architecture. Energy Efficient Data Routing for In-Network Aggregation (EEDRINA) algorithm is incorporated to establish an optimal resource discovery and maintenance mechanism. It institutes an effective data fusion and data aggregation scheme in the sensor grid architecture.

2. Recent Works

Researches related to Sensor Grid have gained popularity in the last decade due to the variety of applications and the development of models. Heterogeneous sensor data is involved in the large scale deployment and multi-hop routing backbone is developed by using the programmable sensor nodes. Visualization of the semantic services is achieved by the service oriented sensor grid architecture [3] [4]. The Primary purpose of integrating sensors and grid computing is to design a real time system framework for decision support for proactive and reactive based events. A novel grid builder tool to identify and control remote and distributive sensors is developed under Collaborative sensor grid framework [5]. This framework is useful in Geo-coded sensor grid applications [6]. The introduction and development of Sensor Web concept is the revolutionary one for accomplishing a collaborative platform for integrating sensor network with web. Various states of art technologies involving comparison of sensor web architecture is presented in [7]. Software tools are vital means for the effective and efficient employment of the sensor networks. Data collected from the distributed sensors are processed by novel resource discovery mechanisms and grid based frameworks are established using the software tools [8] [9]. The concept of Anytime-Anywhere-Anything (A3) is used as resource sharing backbone to afford way in to computational data and storage resources [10]. Generally, the framework involving ambient intelligence is based on vital key technologies such as versatile computing, versatile communication and sharp user interfaces [5] [11]. Geographically distributed sensor devices can be accessible using the A3 concept [12]. Integration of sensor networks with the grid can be established by means of middleware architecture. Data abstraction model with information service based on Sensor Modeling Language (SensorML) can be developed to process real time data resources [13]. To provide circumstantial information and to augment the interoperability necessary for the resource based knowledge discovery, semantic sensor web (SSW) is presented. The Web centric SSW approach is supported by Open Geospatial Consortium (OGC) [14].

To increase the network operations and network life time in the sensor grid architecture, various event driven applications are utilized with mobile sinks [3]. To detect the optimum trajectory of the mobile sinks, regression techniques involving support vector parameters are used. Data gathering from the sensor nodes in the heterogeneous environments is another primary criterion while implementing sensor web architecture. The network coding protocols exploiting two types of feedback, viz, explicit feedback and implicit feedbacks are used for exploring the flow control and sparse codes [6]. Gathering the data from the sensor modes has been incorporated in variety of applications including monitoring and discovery of sensor grid, remote sensing and mining sensory information. In order to improvise the energy conservation parameters, modernized sensor grids using smart sensor devices and operating controllers are used in the real time applications [7]. These devices can be easily monitored and the automated data can be fully functional in flexible and reliable manner. Aggregated data processed through these high level devices can be sent through the Network Operations Centre (NOC) which is located at the utility operation side of the sensor grid. Deployment and replacement of sensor nodes in the cluster and cluster groups in the sensor grid involves stringent response time requirement. The surveillance task analysis implemented in [10] identifies the sensory movement and deployment problems without conserving energy metrics. Hybrid scheme involving sensor movement and secure transmission in the sensor grid with heterogeneous parameters are explored using the scalable key management schemes presented in [13].

With the tremendous growth in the deployment of sensor networks in the real time environment, the achievement of worldwide sensor web has become close to reality. In such cases, serious data management challenges are involved in exploring the benefits of sensor web. For proficient data processing and analysis, regrinding is inevitable. User defined table functions, model based views are used for data abstractions to reduce the non-uniformity [8] [15]. As illustrated in [16], the integration of sensor network to World Wide Web can be done by three methods, independent network, hybrid networking and access point networking. These choices are inspired by the WSN application circumstances. By using Open Sensor Web Architecture (OSA), realization of set of uniformity and typical depiction of sensor data can be achieved without considering the deployment mechanism [10] [17]. To improvise the prediction capability of the object tracking in the sensor grid architecture, various intra gird energy efficient mechanisms are proposed. By using the coverage algorithms, hybrid prediction model is developed based on Markov chain and Grey theory [18]. In data demanding sensor web applications, distributed scheduling schemes are involved to diminish the enormous data loss. Virtual grids are incorporate to reduce the overhead and to handle the sensor mobility [19].

Cyber implementation is one of the pioneering architectures which are flexible to integrate sensor with grid computing. The primary endeavors of cyber implementation are to leverage dynamic sensor data in the grid environment and to guarantee uninterrupted data processing and storage [20]. Testing of sensor devices can be done by using Sensors Suite involving Wireless Sensor and Actuator Network (WSAN) for grid based applications [21] [22]. Also priority and scheduling assignment in the delay sensitive sensors can be implemented using the cross layer data transmission [23]. The Sensor Web Enablement (SWE) can be considered as the building block for the Sensor Web. Implementation of standard protocols and Application Program Interfaces (API) are used to discover and access the sensor data through SWE [24]. Sensor Networks with Web based applications is a relatively up-to-the-minute domain with versatility of applications ranging from target tracking, medium access control, coverage and localization to energy management and information processing [1]. The deployment of sensor networks to virtual communities and social network activities can be explored by the integration of the WSN with the cloud architecture [25]. Recon Figure durable design models can be made using the acceleration sensor networks [26] and innovative solutions can be designed in industrial automation domains like health care, e-commerce and environmental monitoring.

The two major concerns of the Sensor Web are Data processing and Power Management. A cross layer solution for connecting asynchronous power control and continuous query processing is discussed in [27]. Similar cross layer mechanism for Quality of Service (QoS) aware communication framework is established using the suboptimal distributed control algorithm. Multi attribute priority scheduling is achieved to improvise flow control, data delivery and network utility with QoS metrics [28] [29]. Various Energy Aware Cross Layer protocols with the integration of medium access control (MAC), routing, data aggregation and scheduling functions are used in the sensor grid architecture to improvise the energy conservation and network life time [5] [30]. The trust between the cluster sensor location and the transmission schedule is established using such protocols [31] [32]. Heterogeneous energy supply model with energy harvesting (EH) is developed with the aim to optimize source rate utilization and energy consumption [27].

The Rest of the paper is organized as follows: Concept of WSN over Web in Grid Environment is explained in section 3. Problem definition consisting of framework for the Sensor Grid Architecture with Cross Layer Scheduling and implementation of EEDRINA algorithm for resource awareness for Sensor Grid is done in section 4. Simulation Analysis for the cross layer metrics and the discussion about the results of simulation analysis are explained in section 5. Conclusion and the future directions for further research are highlighted in section 6.

3. WSN over Web in Grid Environment

Sensor Web

The concept of Sensor web is primarily developed to observe and investigate new environments with the use of spatially distributed wireless sensor devices which can communicate with each other. Sensor web can be referred as wireless sensor networks (WSN) that are accessible to Web and the data stored can be ascertained and utilized using the standard protocols and application interfaces, as per the statement from the Open Geospatial Consortium (OGC). Sensor web basically has two modules: First one primarily consisting of transducers for interacting with the environment. They interpret environmental parameters into electrical signals. The second one is the infrastructure of the sensor web, *i.e.* telecom facilities, computation devices and power resources those are necessary for the function of the protocol schemas. They are used for analysis of the local data. The Proposed WSN over Web architecture with Cross Layer Scheduling has five layers, OGC Service Provider Layer, Command Execution Layer, Scheduling Cross Layer, Virtual Sensor Network Layer and Adaptive Layer.

OGC Service Provider Layer

The Standard for Sensor Web Enablement (SWE) as defined by Open Geospatial Consortium (OGC) enables experts in establishing the global unified framework of standards. SWE is helpful in connecting diversified sensor related technologies and practices to a common platform. The salient OGC standards included in the SWE are Sensor Observation Services (SOS), Sensor Planning Services (SPS), Sensor Alert Services (SAS) and Mapping Services. SOS is a standard web service interface for interacting with the sensor system information for request, filter and retrieval of data. SPS is web service interface for requesting user initiated activities such as attainment and surveillance. SAS is used for alert information. Publication and subscription of alerts from the sensors can be forwarded through SAS. Mapping is the service used for interlinking different application interfaces. SWE can be used for incorporating variety of applications including traffic monitoring, satellite borne imaging, environmental monitoring, air borne imaging, health monitoring, industrial process monitoring, webcam processing and storing senor data. The diagrammatic illustration of the Sensor Web Enablement (SWE) Applications is represented in **Figure 2**.

Command Execution Layer

The Command Execution Layer consists of Command Manager, Query Manager and Notification Manager. The Command Manager is used for Request-Response Processing. The client request is intercepted and forwarded to a command object. Then the request is processed and final response is delivered to the client by means of the command object. SQL query parsing, planning and execution are completed by Query Manager. All the registered queries are also maintained by the Query Manager. Event delivery, registered query are dealt by Notification Manager for the Sensor based web applications. Customization of application functionality is also done by the extensible architecture available in the Notification Manager.

Scheduling Cross Layer

The Medium Access Control (MAC) layer implementation involving the Cross Layer functionality is established in the Scheduling Cross Layer. The Sensor Web architecture in Grid environment improvises the parameters such as Node waiting status, Used CPU status, Average system utilization, Average utilization per cluster, Cluster usage per hour and Node Energy status by using the cross layer metrics with various resources awareness such as Memory Awareness, Task Awareness and Energy Awareness.

Virtual Sensor Network Layer

Virtual Sensor Network (VSN) Layer consists of container manager objects including VSN Manager, Persistent Manager and Event Manager. VSN Manager is responsible for affording admittance to VSN, sensor data stream delivery management and life cycle management. Management, provision and persistent storage of sensor data stream are done by Persistent Manager. Production and publication of sensor data stream events like missing and arrival of data events are managed by Event Manager.

Adaptive Layer

Communication establishment between the physical sensor network and the drivers for application services is done in Adaptive Layer. Drivers are special type of components used for data acquisition of specific device. The interface applications via Hypertext Transfer Protocol (HTTP), General Packet Radio Service (GPRS), Socket and Serial Interfaces are executed in the Adaptive Layer.

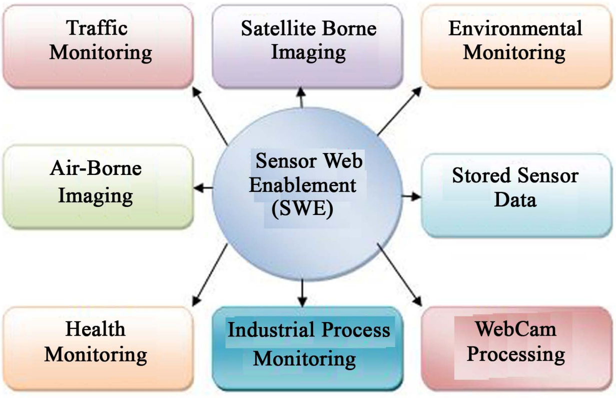

Figure 2. Sensor Web Enablement (SWE)—applications.

Grid Environment

Grid computing can be considered as collaboration of multiple resources from various applications to reach an integrated solution. The grid can be seen as a distributed system with different components that are not interacted with each other but combine together to form a specific application. The heterogeneous feature of the grid makes it different from the usual computational systems such as hierarchical tree structure, cluster computing etc. Grids are generally put up with middleware software libraries. There are three primary grid components available for the general grid computing mechanisms, Software, Data and Computational resources. Their functions collaborate with each other to ensure the heterogeneous operability. Widely used engineering applications for data analysis, processing and computation can be used with grid computing. Also various plug-ins and patches can be added to the existing applications to support grid. This will be very useful for the research community. The Grid Components are represented in **Figure 3**.

4. Problem Definition

WSNoW Architecture with Cross Layer Scheduling

Heterogeneous Wireless Sensor Networks enabled with Web architecture is horded in a container based structure in grid topology. The system complexity of the Sensor Web can be overcome by the provision of such compact architectural array. As far as cross layer scheduling is concerned, the respective resource awareness mechanism has individual algorithm to implement and incorporate in the Sensor Grid environment. Task Scheduling Algorithm is used for Task Awareness. This algorithm is useful in quicker recovery from the saved state on multi-core processor systems. The parallelized algorithm implemented in the proposed framework can achieve speed-up of number of processors. Memory Awareness with Priority Scheduling is used in the framework for improving the CPU utilization and hence the multi-core processor memory. Energy Efficient Data Routing for In-Network Aggregation (EEDRINA) algorithm is used in the energy awareness scheme for optimizing the energy consumption. These three awareness schemes are proposed in the Scheduling Cross Layer of Sensor Grid Architecture. The proposed cross layer scheduling architecture is shown in **Figure 4**.

Cross Layer Scheduling (XLS) Design

The cross layer approach has been considered as the unified approach for reliable and efficient data communication involving medium access control (MAC) applications with the physical layer functionalities. The complete conventional layered protocol architectures can be replaced by the Cross Layer Scheduling (XLM) mechanism. The communication strategies involved in the Cross Layer Scheduling mechanism can be categorized into three sub distributions, viz. initiative concept, initiative determination concept and scheduling concept. The core ox XLM is constituted in initiative concept. For flourishing data communication in the sensor web architecture, a node has to initiate the transmission by sending a broadcast message through RTS packet. It indicates the neighbor nodes that a packet has to be sent by a particular node. In Initiate determination concept, each of the neighbor nodes on reception of the RTS packet is ready for participating in the communication process. Once the readiness of the entire neighbor nodes is analyzed, the scheduling of the data transmission is established by the residual energy of the neighbor nodes. Priority will be assigned via the path involving the neighbor nodes with highest residual energy in the scheduling phase.

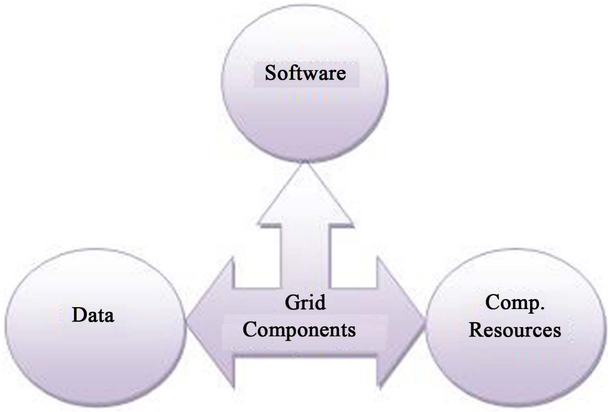

Figure 3. Grid components representation.

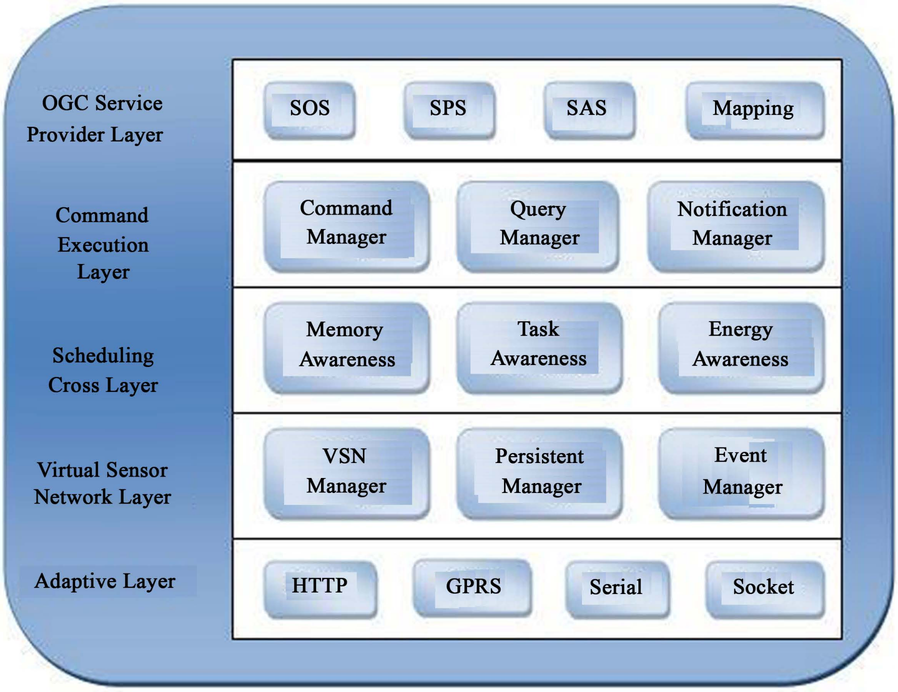

Figure 4. WSN over web architecture with cross layer scheduling.

Representing the Initiative as I, it is denoted as follows:

$$\begin{aligned} &\text{I} = 1, \text{ if } \left\{ \text{SNR}(\text{RTS}) >= \text{SNR}(\text{Th}); \text{RP}_{\text{relay}} <= \text{RP}(\text{Th})_{\text{relay;}} \text{BO} <= \text{BO}_{\max}; \text{E}_{\text{rem}} >= \text{E}(\min)_{\text{rem}} \right\} \\ &\text{I} = 0, \text{ otherwise} \end{aligned} \tag{1}$$

where SNR(RTS) is the received Signal to Noise Ratio of the RTS packet, SNR(Th) is the threshold value for the received Signal to Noise Ratio, RP_{relay} is the rate of transmission of the packets from the individual node, $RP(Th)_{relay}$ is the threshold for the rate of packets, BO is the buffer occupancy of the individual node, BO_{max} is the maximum threshold value for the buffer occupancy, E_{rem} is the residual energy remaining in the individual node and $E(min)_{rem}$ is the minimum threshold value for the residual energy. The four conditions formulated in (1) have to be established for the initiative concept. The conditions can be described as follows:

1. SNR condition confirms the need for the reliable communication links between the nodes,
2. Rate of Packets condition ensures the limitation of traffic sent by the individual node and prevents congestion in the communication network,
3. Buffer overflow, rd, condition restricts the buffer overflow in the individual node,
4. Residual energy condition validates the residual energy of the individual node being above the minimum threshold value for scheduling.

Cross Layer Resource Awareness

The network protocol design for the sensor web architecture can be inferred as distributed solution at multiple layers. The concept of Resource awareness has been established with the intention of network lifetime maximization, energy consumption minimization and performance improvisation. Most of the existing techniques implement the resource awareness in the individual layers and hence the optimization across the layers is not established. Heuristic approach addressing this problem finds way for Cross Layer Resource Awareness Scheme. The optimization for cross layer resource awareness can be defined as follows:

$$\begin{aligned} &\text{R}^{\text{opt}}: \text{Cross Layer Resource Awareness, Given}: \text{E}^{\text{p}}{}_{\text{s}}, \text{l}_{\text{ab}}(), \text{c}_{\text{ab}}(), \text{d}^{\text{s}}: \text{Find}: \text{br}, \text{pv} \\ &\text{Minimize}: \textstyle\sum_{s\in S} \text{OU}_{\text{s}}(\text{br}_{\text{s}}) + \sum_{b\in N} \text{OV}_{\text{b}}(\text{pv}_{\text{s}}) \end{aligned} \tag{2}$$

where $E^{p}{}_{s}$ is the vector with the generic aspect representing decoding error probability, l_{ab} is the link associated delay between the nodes a and b, c_{ab} is the link associated capacity expression between the nodes a and b, d^{s} is the source associated delay, s is the source node under transmission and S is the total group.

The condition is to find out the values of bit rate (br) assigned to the source and power vector (pv) transmitted and to minimize the coordinate function as defined in (2). The Total summation values of sum of objective utility function based on source (OU_s) and sum of objective vector function based on individual node (OV_b).

Middleware Cross Layer Scheduling Framework

Heterogeneous wireless sensor network with web in grid environment consisting of hundreds of sensor nodes is considered. Data gathering and processing are done by each and every node in the grid environment. The data collected from the source is transmitted to the sink by means of intermediate In-network data aggregation path. The primary objectives of this work is to design a middleware architectural framework using the cross layer scheduling with resource discovery and energy conservation in the Sensor Grid and to analyze the various cross layer metrics such as Memory Awareness, Task Awareness and Energy Awareness. Sensor web architecture systems are dynamically distributed event based systems. Normal traditional sensor networks have various systematic constraints including high energy drain rates, low data communication rates etc. For performing the in-network aggregation, data centric mechanisms are needed. In this paper, data routing for In-network aggregation is proposed. The impact of the sensor node density and the integration of the sensor nodes with the heterogeneous applications in the grid architecture for measuring the resource awareness metrics can be compared with the middleware cross layer scheduling. Considerable resource awareness gain is achieved by implementing Route Discovery and Maintenance procedures for Task awareness, CPU and Node utilization metrics are improved for Memory awareness and Data fusion and structured data aggregation measures are implemented for Energy awareness.

In parallel processing environments involving heterogeneous applications, asynchronous algorithms are used to improve scalability and reliability. Asynchronous distributed algorithms are preferred in sensor based applications since data aggregation flow from the source to sink across multi-hop, multi-node environment involves heuristic processes. In this paper, we have formulated straight forward asynchronous distributed algorithm in which the data aggregation measures are performed in the iterative basis. Hierarchical computations with dynamic distributed layer wise aggregation are executed in the algorithm which measures better resource awareness. The framework for the middleware cross layer scheduling is shown in **Figure 5**.

EEDRINA Implementation

The primary aim of the Energy Efficient Data Routing for In-Network Aggregation (EEDRINA) algorithm in

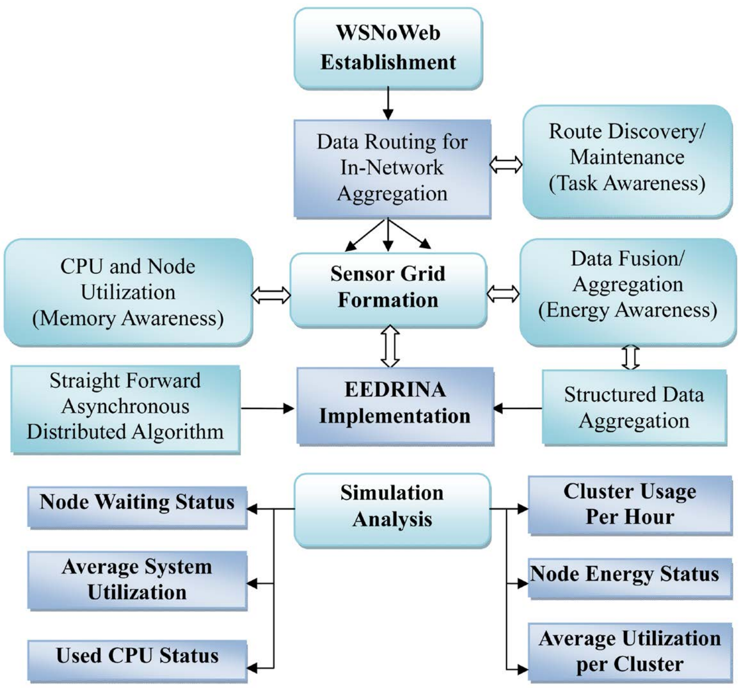

Figure 5. Middleware cross layer scheduling framework.

the implementation of cross layer scheduling is to establish an optimal resource discovery and maintenance mechanism and to institute an effective data fusion and data aggregation scheme in the sensor grid architecture. The EEDRINA algorithm can be implemented in four stages.

1. Building Hop Tree from Sensor Nodes to Sink: In step 1, establishment of multi hop communication between the individual sensor nodes to the sink is done for data forwarding. For each node receiving the message, the hop length is measured and if the length is greater than that of Hop Communication message, the formation of hop tree is extended and the node id is updated. For incrementing the process, the node updates the value to hop communication message and sends the broadcast message.
2. Cluster Formation and Cluster Head Selection: In step 2, identification of homogeneous nodes and grouping of nodes as cluster take place. For each node belonging to the set, the node sends the broadcast for event detection. If the hop pertaining to the particular node is greater than the given set, the node retransmits the message received and assigned and leader or else the node discards the message received from the set. Also in step 2, selection of the cluster head based on the geographical position, data forwarding and residual energy parameters calculation are done.
3. Event Detection: In step 3, Route establishment and Maintenance for the data forwarding and setting up of such routes for data packet delivery and hop tree updation is done. In event detection, initialization of node broadcasting to hop communication message takes place based on the residual energy of the intermediate node relay. The process is repeated until the node identifies the route structure. Data aggregation is forwarded to all nodes and the data is sent to further hops based on the availability of data in the source end.
4. Energy Conservation: In step 4, energy conservation is the prime function. Effective saving of energy of the sensor and the cluster heads by proper rerouting of data via appropriate cluster heads using the resource discovery and straight forward asynchronous distributed algorithm is done. Energy threshold for the individual nodes is set based on the average node energy of the network. At a given time, if the node energy of the leader node is lesser than the average node energy, the step 2 is repeated with new cluster formation. Until then, data aggregation is continued. For selecting the nodes for hop communication, the step 3 *i.e.* event detection is continued for data to be transmitted. Energy is conserved based on these iterative processes.

The Data flow diagram for the implementation of EEDRINA Algorithm is shown in **Figure 6(a)** and **Figure 6(b)**.

5. Simulation Analysis

The simulation analysis is carried out in the Sensor Grid Tool for the metrics, Memory Awareness, Task Awareness and Energy Awareness for Sensor Grid with Middleware framework. For comparative analysis, the parameters, viz. Node waiting status, Used CPU status, Average system utilization, Average utilization per cluster, Cluster usage per hour and Node Energy status are observed for the sensor grid architecture framework with and without middleware cross scheduling framework. The parameters and the values used for the simulation analysis are available in **Table 1**.

Table 1. Simulation metrics for sensor grid with middleware architecture implementation.

Simulation Parameter	Simulation Value
IEEE Standard	IEEE 802.15.4
Network Size	1024
Configuration Tool	Sensor Grid/Alea Version 2.0
Algorithm	Energy Efficient Data Routing for In-Network Aggregation (EEDRINA)
Protocol Layer	Cross Layer MAC
Antenna	Omni Directional
Channel Propagation	Wireless/Two Ray Ground
Network Field	1500 m × 1500 m
Proposal	Resource Awareness with/without Cross Layer Scheduling

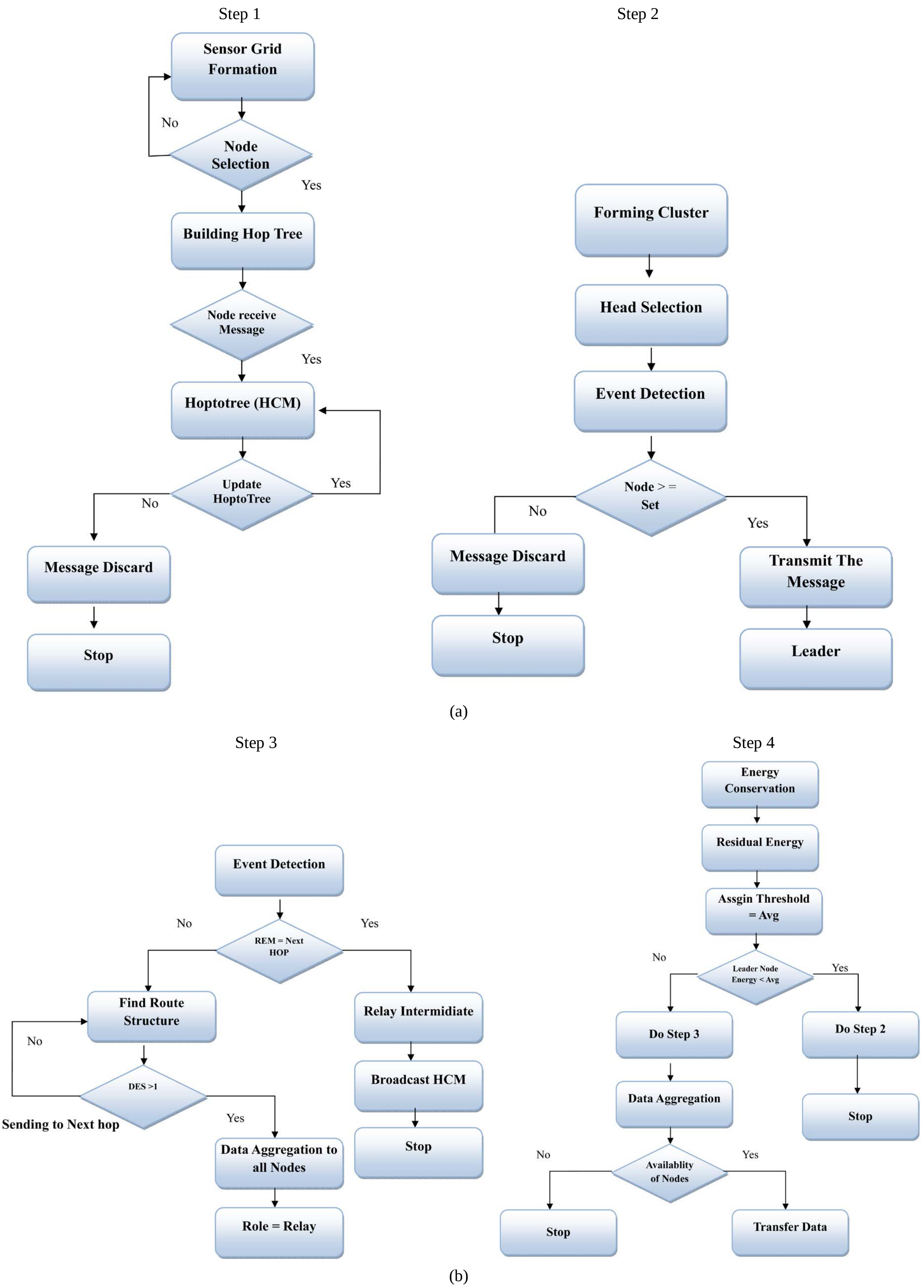

Figure 6. (a) Data flow diagram for EEDRINA algorithm; (b) Data flow diagram for EEDRINA algorithm.

Simulation Environment

The following parameters are measured in the simulation analysis:

- Node Waiting Status: Number of nodes waiting in the queue during the system processing,
- Used CPU Status: Percentage of CPU memory used during the system processing,
- Average System Utilization: Percentage of the system utilized over a period of time,
- Average Utilization Per Cluster: Percentage of the system utilized with respect to particular cluster over a period of time,
- Cluster Usage Per Hour: Ratio of the utilization of nodes in a particular cluster for per hour basis,
- Node Energy Status: Ratio of remaining energy of the nodes in the system over a period of time.

6. Results and Discussion

Figure 7 represents the diagrammatic representation of the system performances in the Sensor Grid/Alea version 2.0 tool.

The Comparative analysis for the Sensor Grid Architecture with and without Middleware framework is illustrated below.

Experiments are conducted in sensor grid architecture with and without middleware framework. Query for Node waiting is less while middleware framework is involved whereas the queue size is gradually increased when middleware framework is not involved in the sensor grid. This shows that with middleware framework, the waiting status of the nodes can be reduced. This is illustrated in **Figure 8**. With the introduction of Middleware framework using task awareness, the number of jobs executed in the given time is getting increased and hence the queue waiting status is gradually reduced which can be noticed from the simulation analysis.

The percentage of the memory of the CPU utilized can be measured over a particular period of time. Sensor grid with Middleware framework has minimum utilization of CPU compared to the sensor grid without middleware framework. CPU utilization status is shown in **Figure 9**. The memory awareness established in the middleware framework is used in effectively reducing the CPU utilization and hence shows better performance when compared to the system without middleware framework.

Similarly the Average system utilization is also improved by the cross layer scheduling mechanism of the middleware framework. The overall system utilization is improved up to 20% by implementing the proposed framework, which in turn is the indicator of the effective sensor grid model. The Average utilization per cluster for the system with and without Middleware framework is compared in **Figure 10**.

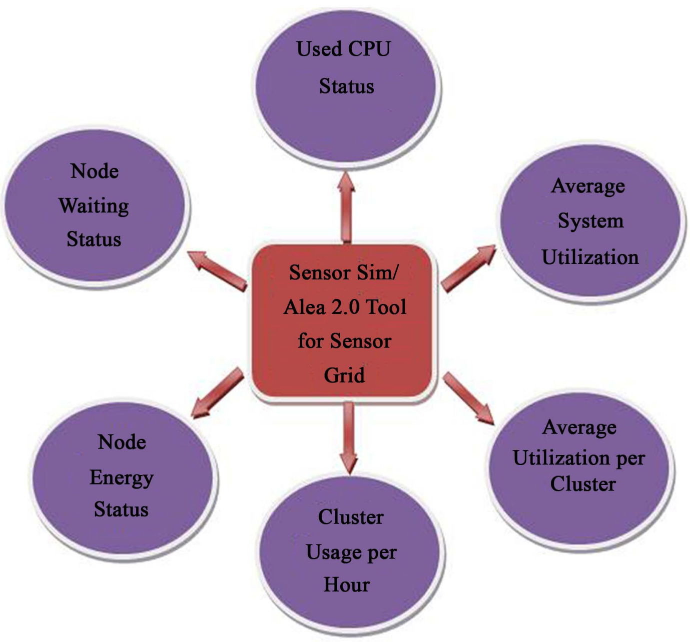

Figure 7. System performances in the sensor grid/alea version 2.0 tool.

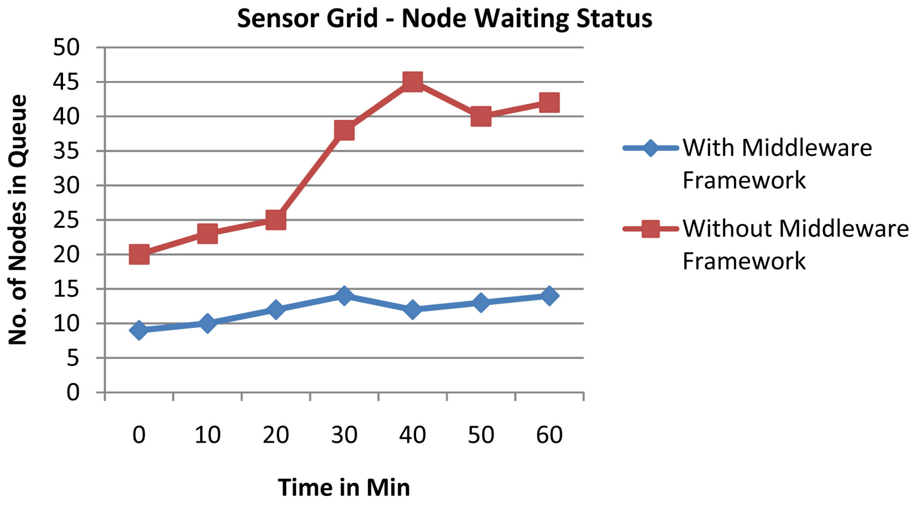

Figure 8. Sensor grid—node waiting status.

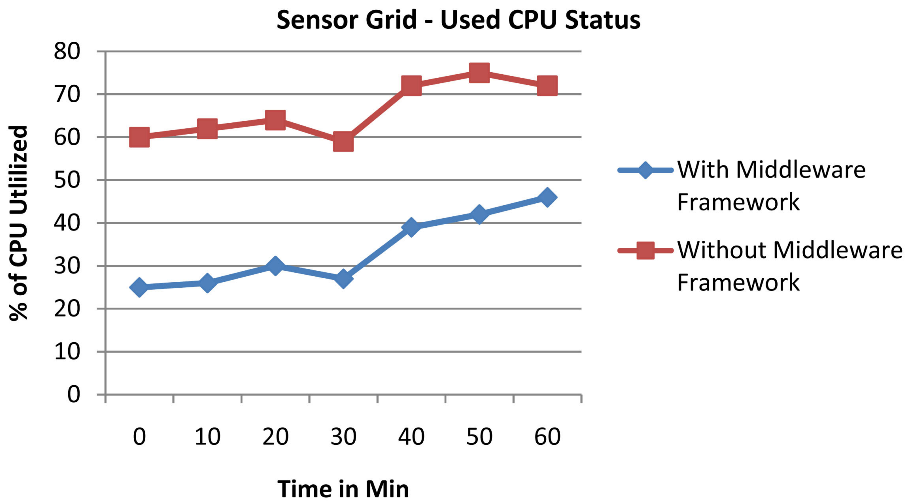

Figure 9. Sensor grid—used CPU status.

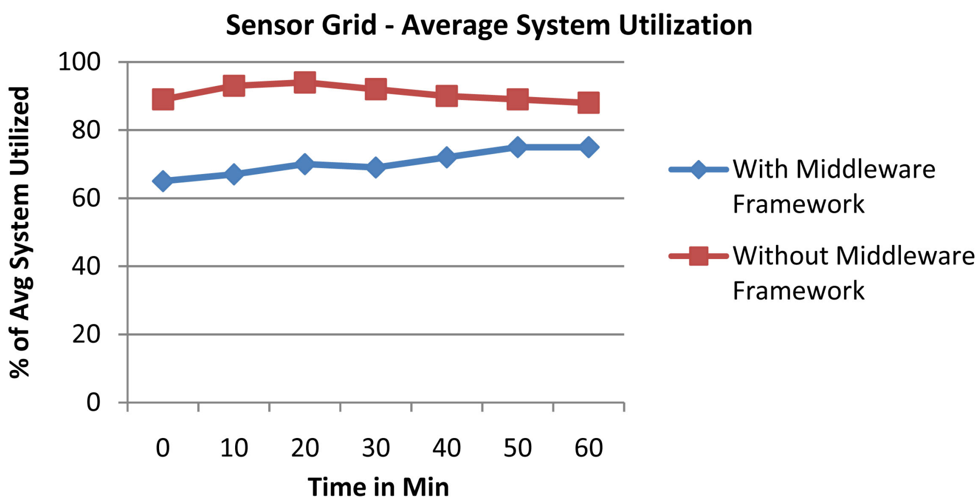

Figure 10. Sensor grid—average system utilization.

The system performance with respect to the independent cluster in the sensor network has also shown better performance while implementing using Middleware framework with cross layer scheduling. This is show in **Figure 11**. Over a period of time, the system utilization performance shows a steady level in the implementation for middleware framework with cross layer scheduling.

In the sensor grid architecture, the usage of clusters in per hour basis is calculated and the middleware framework has lowest utilization value. This is shown in **Figure 12**. For the data transmission capability of the heterogeneous sensor devices within the cluster can be analyzed and the percentage of cluster usage based on the linear time scale is compared for sensor web architecture with and without middleware framework.

The residual energy remaining in the node during the data transfer at the particular period is the measure for increasing the network lifetime of the system. With the introduction of cross layer mechanism in the middleware framework, effective data fusion and aggregation nodes take place. This lead to reduction in average energy utilization and hence lifetime of the node is getting increased. The energy status of the node in the sensor grid architecture is calculated in the experimental analysis. The residual energy available in the node is measured over a period of time for both the simulation environment. Sensor web architecture with middleware framework and cross layer scheduling utilizes less energy per node when compared to the normal framework which is evident from the graph shown in **Figure 13**.

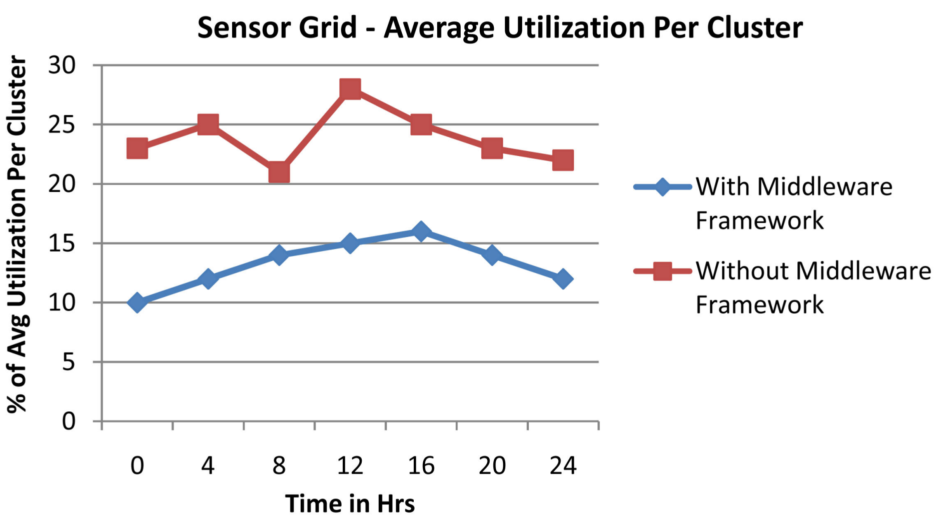

Figure 11. Sensor grid—average utilization per cluster.

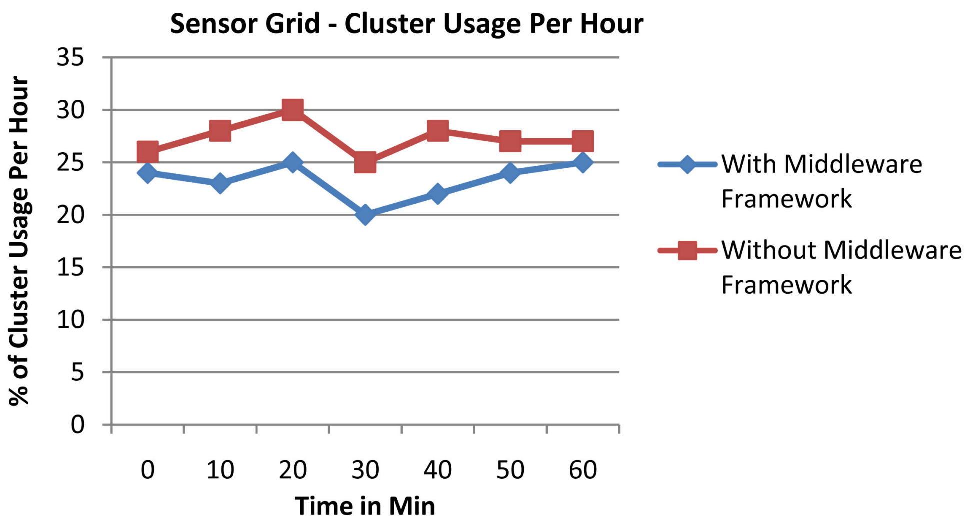

Figure 12. Sensor grid—cluster usage per hour.

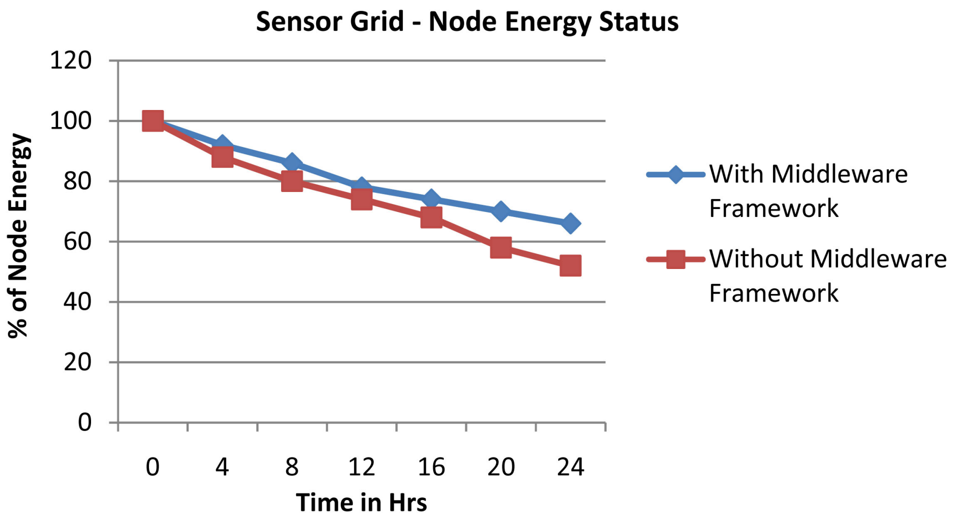

Figure 13. Sensor grid—node energy status.

7. Conclusion and Future Works

In this paper, we have presented Sensor Grid based architecture with middleware framework containing cross layer scheduling mechanisms. Resource Awareness metrics, viz. Task, Memory and Energy metrics are implemented by using the proper resource discovery and maintenance schemes. Straight forwarded asynchronous distributed algorithm along with Energy Efficient Data Routing for In-Network Aggregation (EEDRINA) algorithm is implemented in the middleware framework to improve the resource awareness metrics. The simulation results using the sensor grid/Alea version 2.0 tool show that the inclusion of middleware framework in the sensor grid architecture has led to effective system processes in terms of task, memory and energy metrics. Wireless Sensor Network over Web (WSNoWeb) architecture with cross layer scheduling mechanisms in the Grid environment is better suited for process intrinsic system applications like remote sensing, cyber implementation, weather forecast, collaborative sensor networks etc. Thus the framework with the newly proposed scheduling cross layer framework achieves memory awareness, task awareness and energy awareness in the sensor grid architecture. As a future direction, we can extend this work by integrating the Cross Layer Sensor grid architecture with the heterogeneous networks to present an overall Distributed Grid framework.

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