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INVESTIGATIONS ON TASK AND ROLE ASSIGNMENT PROTOCOLS IN WIRELESS SENSOR NETWORK

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ABSTRACT

Wireless sensor networks (WSN) have gradually evolved along the years in terms of hardware, protocols and standards. The multifunctional sensor nodes (MSN) have improved in terms of power, communication range, memory and battery capacity. Wide range of WSN applications such as environment monitoring, health monitoring, military applications, video surveillance, natural disaster detection, seismic sensing, etc., are based on multifunctional sensor nodes. The multifunctional sensor nodes are capable of performing similar tasks or roles with different quality of service parameters. The assignment of roles and task to the suitable sensor nodes would ensure the increase in performance and longevity of the network. This paper investigates the various existing task and role assignment algorithms and also highlights the various research challenges. The investigations are carried out in terms of computational complexity, robustness, communication complexity, network lifetime and energy consumed for task and role assignment algorithms.

Keywords: *Task, Role, Task Assignment, Role Assignment, Multifunctional sensor node, Wireless Sensor Network.*

1. INTRODUCTION

Recently, the field of WSN has grown tremendously and plays an inevitable role in our day to day lives. In the recent past, the applications of WSN has evolved from simple to critical and complex applications such as environment monitoring, military applications, natural disaster detection, seismic sensing, health monitoring, video surveillance, satellite based applications etc. [4] The phenomenal advancements of sensor nodes in terms of processing power[20,21], size [20], high precision sensing [19] and multi sensing functionality[13, 27] has led to various research challenges in wireless sensor network. A multifunctional sensor node(MSN) has multiple sensors and is capable of performing one or multiple sensing task at a given instant[14]. Due to recent advancements in micro-fabrication techniques, multiple sensors could be integrated to a sensor node [17,27]. Waspmote[26], Mica2[16, 17], MicaZ[16,30], TelosB[6] etc. are also few examples of the MSN that enables user to embed desired sensors on a multifunctional node. For example, a multifunctional node [27] is integrated with heterogeneous sensing sensors like humidity, temperature, light intensity, pressure, wind speed, wind direction, magnetic field and acceleration sensors.

In a WSN application, few MSN's could replace numerous legacy sensor nodes [17, 19]. The WSN applications running with few MSN's is relatively less complex than the WSN application that runs with numerous legacy nodes [17]. Deployment, replacement, reconfiguring and maintenance of the MSN's are also relatively less complex with respect to WSN application running with few multifunctional nodes[13]. A WSN application could have either homogenous or heterogeneous set of nodes. Homogeneous network is constituted by a set of homogeneous nodes that have same quality of service parameters. Heterogeneous network is constituted by a set of heterogeneous nodes that have different quality of service parameters. Assigning task in heterogeneous network is more complex than in homogenous network, due to the variation in quality of service parameters. A MSN

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could be equipped with heterogeneous sensors and as well as homogenous sensors with same or different Quality of Service (QoS) parameters [27]. Role and task assignment in WSN with multifunctional sensor nodes is a major research challenge [8]. This is due to the fact that role assignment in a heterogeneous multifunctional node is much more complex than role assignment in homogeneous multifunctional network, as each node is equipped with similar or different set of sensors with different QoS parameters. This paper aims at investigating the various role and task assignment algorithms and also discuss the pros and cons of the algorithms.

Section 2 discusses about related work with regard to the task assignment and role assignment. Section 3 presents the various investigations performed on the task and role assignment with respect to performance metrics in wireless sensor network. Section 4 concludes the paper with future scope in the area of role and task assignment.

2. RELATED WORK

An extensive literature survey has been carried out to investigate the research challenges in task and role assignment protocols in WSN. Investigations are based on the quality of service parameters for task and role assignment algorithms.

2.1 Task Assignment

The tasks are to be optimally assigned to the multifunctional sensor node such that the overall performance and life time of the network should be maximized.[3] Selection of the node for task assignment is influenced by the quality of service parameters such as task priority, task deadlines, energy required and task completion time. Selecting and assigning an appropriate node for performing task by satisfying the quality of service parameters is a major research challenge. Therefore task assignment with multifunctional sensors is gaining much interest. Robustness, an important criterion has to be considered during task assignment as the WSN are prone to errors like sensor node failure and communication failure. Based on architecture, the wireless sensor network is classified as centralized and distributed [1,20].

2.1.1 Centralized approach

Task is assigned by a central node to other sensor nodes. Centralized approach is more suitable for a C2 WSN as the computational complexity is less[20]. C1WSN has high computational complexity.[20] Communication cost is higher due to the large number of control packets. Few of the centralized task assignment approaches are EBTA [24], ITAS [7], HITAS [7], task management [12] etc.

Yu et al. proposed an Energy- Balanced Task Allocation (EBTA) for single hop cluster of homogeneous sensor nodes[24]. EBTA addressed task assignment by adapting Dynamic Voltage Scaling (DVS) mechanism to control the voltage setting of a task and scheduling of communication and computational activities. The authors proposed two task allocation methods namely Integer Linear Programming (ILP) method and 3-phase polynomial heuristic method to solve the task allocation problem. Phase 1 of the polynomial heuristic method combines various tasks as clusters in order to reduce execution time. Phase 2 assigns task cluster to nodes based on the remaining energy. Phase 3 uses iterative greedy heuristic algorithm to alter the voltage levels of task. Both the task allocation methods in EBTA were specifically designed for static homogenous legacy nodes. The methods fall short in addressing robustness, scalability, task deadlines, task priorities and task energy. Network life time of 3phase heuristic approach was 63% higher than ILP method. Computational complexity was given as $O(d.n(n+e+logn)+e^2+m.n)$ where e is counter in phase 1, *c* is counter in phase 2, *m* is the possible assignment, *d.n* is the voltage switching. Single hop communication reduced the overall communication overhead.

Tao Xie et al. proposed heuristic Balance Energy Aware Task Allocation (BEATA) scheme[18] for task allocation in heterogeneous wireless sensor network. Task was modelled using Directed Acyclic Graph (DAG) that helped in prioritising the tasks. BEATA proposed Energy Adaptive Window (EAW) that has node id, energy required by the node to perform a task of all nodes in the window and make span time of the task. The EAW was sorted based on the make span time and node id with lowest energy in the EAW limit was selected for task assignment. EAW also considered energy required for communication and computational tasks. DVS could be used additionally to reduce energy consumption. BEATA did not address the issues of robustness, scalability, task deadline. Communication overhead was considered low as BEATA uses single hop communication. It outperformed LIST [18] and GEATA [18] schemes in terms of task

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execution time and energy consumption. Computational complexity was found to be $O(n^2)$.

Tian et al. proposed Multi hop Task Mapping and Scheduling (MTMS) algorithm [25]. The algorithm achieved the required in-network processing capacity for real-time applications in multi-hop homogenous WSN. MTMS have task mapping and scheduling phase along with DVS phase. MTMS adapts broadcast communication. Hyper-DAG is an extension of regular DAG that considers task priority. Task Schedule Search Engine (TSSE), an extension of Min-Min algorithm was used to reduce energy consumption. Task deadline is also considered as a parameter. MTMS could process communication and accommodate computation tasks and accommodate parallel tasks. MTMS achieved low energy consumption than EBTA[24]. Computational complexity of TSSE and DVS algorithm was given as $O(e.n.s.k + \left(n + \frac{n^2}{s}\right))$. MTMS used broadcast based multi-hop communication to reduce the communication overhead. For densely populated cluster, MTMS outperforms distributed computing architecture[25] resulting in lower deadline missing ratio and better network life time.

Dieber et al. proposed a combination of centralized coverage and task assignment scheme[21] for visual sensor network. The objective was to select and configure the camera nodes based on QOS parameters and assign tasks to camera nodes. It adapted genetic algorithm and expectation-maximization algorithm for efficient approximation and optimization respectively. Task energy, task deadline, scalability, DVS, robustness, dynamic settings of the network and camera nodes in mobility states were not addressed. It's computational complexity *is* $O(f\ (r + x))$ where f, r, x are the counters for fitness, mutation and crossover function respectively. Mezei et al. proposed task assignment scheme based on auctions and information mesh(iMesh) for wireless sensor and actuator network[5]. They used localized K-hops simple auction aggregation protocol (K-SAAP) for assigning task to the nearest actuator for data aggregation. Mobility, scalability, robustness, multiple and parallel tasks were not addressed. K-SAAP overcame the flooding problem by introducing k-hops leading to less communication overhead. The communication cost of iMesh was less than quorum service discovery [5].

Jin et al. proposed Intelligent Task Allocation Scheme (ITAS) [7] & Heuristic Intelligent Task Allocation Scheme (HITAS) designed for multi hop wireless sensor network. ITAS network was designed for centralized heterogeneous nodes and the application was modelled as direct acyclic graph. ITAS used genetic algorithm for task assignment scheme. ITAS convergence rate was delayed for a very large network due to random initial population. Heuristic inspired intelligent task allocation and scheduling (HITAS) was designed. HITAS used heuristic methods for generating initial population. HITAS and ITAS considered deadline missing ratio as a parameter. HITAS & ITAS have computational complexity of $O(f.x))$ where f, x are the counters for fitness function and crossover functions respectively. Network Life time varies each time as the chromosomes generated changed during every reorganisation phase. Each node has to convey its current status during the reorganisation phase leading to high communication overhead. Adding and removal of nodes were possible only in reorganisation phase. Le et al. proposed Generalised Assignment Problem -E(GAP-E) algorithm[15]. It used multi round knap-sack algorithm to assign tasks. Energy requirement and deadline of computational task, mobility, and scalability were not taken into consideration. GAP-E considered tasks as demand in knapsack and finds the ideal task assignment. The computational complexity of GAP-E is $O(t.n\ )$ where *t,n* is the no of tasks and nodes respectively. The algorithm was compared with Exclusive Sensor Mode(ESM) that enables only one task to taken up at a time and Shared Sensor Mode(SSM) that was similar to ESM but had task to be shared between sensors. SSM without demand checking (SSM-NC) enabled the highest utility value to be the final task allocation. MSM computational complexity was less than ESM.

2.1.2 Distributed approach

Task assignment is done by multiple controllers distributed on to the network. These controllers perform the task scheduling locally within their cluster. Computational complexities of distributed algorithm is less for a densely populated network when compared to centralized approach since the network can be divided to manageable size [1,20]. Some of the task assignment algorithms are based on distributed architecture are DLMA [23], TAN[1], [11].

Carlos et al. proposed a distributed task assignment[11] scheme for mobile sensor

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network. It used Min-Max Algorithm for assigning task based on static events. On discovery of an event, the task urgency was calculated and an invitation was issued. Nodes on receipt of invitation, checks the urgency of the task, time stamp and availability for the task execution. The invitation is forwarded to the neighbouring nodes updating the invitation and its time stamp until a node accepts the invitation. Robustness was achieved via distributed counting algorithm based on the consensus protocol. Aggregation or gossiping algorithm was used to facilitate the distributed counting algorithm to be asynchronous. Mobility, heterogeneity, scalability, deadline of tasks and parallel execution of the tasks were not considered. The computational complexity was found to be $O(n)$. Communication overhead was relative higher since gossiping was used. Pilloni et al. proposed Task Allocation Negotiation (TAN) [1] algorithm that adapted non-cooperative game theory. It provided an adaptive and distributed task allocation scheme for clustered heterogeneous wireless sensor network. TAN used greedy search algorithm called distributed stochastic algorithm for negotiation between nodes. TAN considers task priority, application completion time. TAN didn't address the issues of mobility, robustness, heterogeneity, task deadline. It outperformed DLMA[23] and centralized solution[10] in terms of energy consumption and application completion time. Computation Complexity was found to be $O(n^2)$.

Pilloni et al. proposed a Distributed Lifetime Maximization Algorithm (DLMA)[23] for distributed WSN. The algorithm used an iterative gossip and asynchronous local task allocation scheme. DLMA did not address the issues like scalability and robustness. The algorithm had better network lifetime in comparison with methods like centralized solution [10]. Computation complexity was higher than TAN [1]. Asynchronous local task allocation method facilitated finding faulty nodes. Communication overhead caused by iterative gossiping was high. Chen et al. proposed an asynchronous distributed task allocation algorithm based on Contract Net Protocol(CNP)[8]. Tasks generated by the task node are communicated to manager node. On receipt of the task, manager node initiates inviting bids from ordinary nodes. Each bid was constituted by the node's residual energy, waiting time of task in the queue etc. Contract net utilizes bidding process to complete task negotiation. The use of C-MEANS clustering algorithm enhanced the contract net method by grouping similar task resulting in Improved-CNP (ICNP). The nodes were clustered in to group based on similar characteristics. The task allocation algorithm considered energy of the task as the parameter. The method did not address the execution of multiple and parallel task. Improved contract net protocol outperformed legacy contract net protocol in terms of energy. Energy consumption by CNP was 0.008455962J and I-CNP was 0.00604233J for 10 tasks. The total traffic flow in CNP was 50739 bit, and that in ICNP was 81371 bit for 10 tasks. The number of tasks successfully completed was higher in ICNP than CNP by 100 in the duration of 20 minutes.

Yang et al. proposed meta heuristic task allocation scheme using Modified Binary Particle Swarm Optimization (MBPSO)[3]. Network model was designed for heterogeneous sensors. Tasks to be assigned were modelled as DAG. DAG considered higher priority task and prerequisite job in the top position followed by the rest of the tasks. Each task allocation solution was considered as a particle. And the best particles were identified by the fitness value. The objective function was calculated based on task execution time, energy consumption and energy distribution. MBPSO uses either 1 or 0 to decide whether a node was selected for a task or not. Communication and computation task were scheduled. The MBPSO utilizes parallel computing capability of the wireless sensor network to assign multiple tasks to a node. Adding and removal of nodes were only possible in reorganisation phase. MBPSO considered task based on priority. Communication overhead was comparatively high as each node has to update its QoS parameters every time in the reorganisation phase. Robustness was not addressed. MBPSO outperforms genetic algorithm and BPSO in terms of success rate and solution quality leading to better network lifetime.

2.2 Role Assignment

Role assignment in WSN is the process of assigning role to nodes in a group based WSN application[14]. Each role has different tasks and may use different resources from different nodes to complete the task.[14] Role assignment is based on the following criteria such as node's remaining energy[9,17, 14], reputation[9], bootstrap time[9], sensor availability[9] in addition to task priority, task deadlines, energy required and task completion time.

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The process of role assignment could be synchronous [9] and on-demand[14] throughout the life span of the network. Role assignment could be classified as proactive and reactive [14]. Proactive role assignments are primarily assigned before detection of an event. Proactive role assignment utilizes more energy in idle time. Reactive role assignments are dynamically assigned on detecting an event. Reactive role assignment may cause time delay to respond to an event.

2.2.1 Proactive role assignment approaches

Misra et al. proposed Reputation based Role Assignment Scheme (RRAS) [9]. The algorithm provided access control to the node via role assignment in a hierarchical manner. Role assignment proposed was based on the weighted average of reputation, energy and bootstrap time. Task priorities were included via roles. Energy required for a task, task completion time, mobility of the nodes, Dynamic Voltage Scaling (DVS) of nodes were not addressed in the role assignment scheme. RRAS enhances the throughput, network lifetime and lowers the overall energy consumption. Computation complexity of RRAS was found to be $O(\mathrm{n})$. Communication overhead occurs in re-organization phase, every node sends it current energy level, network life time to the base station for the role assignment. Panja et al. proposed Role Based Access in Sensor networks (RBASH) for multilevel hierarchical homogenous network [17]. Role assignment to multilevel hierarchical network architecture was performed based on energy. RBASH considered secure key distribution. RBASH did not address the issues like mobility, robustness and scalability of the nodes, DVS, task deadline, task energy, task completion time. Higher priority tasks were given to node in the higher level of the hierarchy. Computational complexity was high in comparison with RRAS [9]. It outperformed SPIN[17] in terms of less usage of bandwidth and energy. RBASH saves energy than µTesla[17] but utilizes more bandwidth.

Abdel Salam et al. proposed two energy aware task management protocols for work force selection[12]. It aimed at longer life time of the network lifetime. One was specifically designed for centralized and the other method was designed for distributed system. It proposed various roles such as candidate sensors, leader for effective workforce selection. The workforce selection was based on contention. The leader nodes were heavily loaded in the centralized approach resulting the authors to propose the distributed method. In distributed approach the contention algorithm was used to decide the maximum energy among the work force. The node would decide to participate in the task execution based on the nodes current energy and maximum energy of the group. Heterogeneity of nodes, DVS, mobility, robustness and scalability of the nodes were not addressed. Flooding problem was an important challenge of contention based approach leading to communication overhead. Workforce selection algorithm phase ensured the network life time was higher.

2.2.2 Reactive role assignment approaches

Nakamura et al. proposed Information-Fusion based Role Assignment (INFRA) [14] for routing. INFRA a heuristic role assignment scheme was designed for static event driven distributed network. INFRA assigned roles based on smallest id or largest residual energy or highest degree. INFRA was compared with two reactive variants namely, shortest path tree and centred-at-nearest source tree and it outperformed the compared methods in finding the routes. Detection of event at any instance caused INFRA to flood control packets to the entire network causing higher communication overhead. Computational complexity is of $\mathrm{O}(\mathrm{n}^2+\mathrm{D.n}+\mathrm{m.n})$. n^2, $\mathrm{D.n}$, $\mathrm{m.n}$ represented the overhead due to communication cost, hop count cost and messaging cost respectively. Tuna et al. proposed a systematic deployment system of wireless sensor network using mobile robots to detect human lives in a disaster scenario[2]. This work addressed simultaneous localization and mapping(SLAM) problem. Mobile robots performed the role of explorers and relays. Sensor nodes were assigned as relays and were responsible for the communication between the control centre and the explorers. Scalability, robustness, DVS, heterogeneity of the nodes, parallel task assignment were not addressed. Computation complexity was found to be $O(n^2)$.

Yunus et al. proposed Event Based Fairness (EBF) scheme[6]. It was designed for distributed multimedia sensor network. The scheme aimed to optimally allocate resources in the multimedia sensor network using packet queue and contention window of the events. It introduced two type of routing based on paths. History based Least Attained Service(HLAS) was designed for single path routing. Network allowing multipath routing was scheduled using Distributed Least Attained Service(DLAS). DLAS with Differentiated Contention windows (DC-DLAS) offered better fairness of events at different nodes by varying the

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contention windows based on task priority. Mobility, scalability, DVS, heterogeneity of the nodes, task deadline were not addressed. Johnson et al. proposed four optimal role assignment algorithms[13]. Greedy algorithm was designed for static centralized structure and made to reach the highest important role. Its complexity was given as $O(m.n\,(m+logn))$. Multi-round GAP (MRGAP) could be implemented both in centralized and distributed structure. MRGAP used combinatorial auction algorithm. Computational complexity of MRGAP was given as $O(m.2^n)$ and it marginally outperformed greedy algorithm in the static scenario. For the dynamic setting, energy-aware (E) scheme and combination of energy and lifetime (E/L) aware scheme were proposed. MSN and parallel processing capability of the nodes was not addressed. E/L- aware scheme outperformed E-aware scheme in terms of selecting the important role and better lifetime. Mobility, scalability, robustness, DVS, heterogeneity of the nodes, parallel task assignment were not addressed.

3. INVESTIGATIONS ON THE PERFORMANCE OF ROLE AND TASK ASSIGNMENT ALGORITHMS

In this section, the performance of the existing algorithms has been investigated. The various investigations performed were computational complexity, robustness, communication complexity, energy consumption and network lifetime during task and role assignment. The investigations were made based on the properties of a node, Cluster Head (CH), Head of Cluster (HCH) and Base Station (BS).

3.1 Computational Complexity

Role and task assignment problem are multi-objective problems [29,1]. The computational complexity of task and role assignment algorithms in distributed network is relative less than centralised approach with large WSN [12]. Nature based algorithms like genetic [7], BPSO[3] generate stochastic solutions based on fitness function, mutation, crossover etc. Computational complexity of nature based algorithms is more and is suitable for densely populated network. Technique like divide and conquer [8] was introduced to reduce the complexity of assignment problem. Table 1 and 2 tabulates the computational complexity of the algorithms.

Table 1: Computational Complexity And Robustness Of Task Assignment Algorithms.

Algorithm	Robustness	Computation complexity
EBTA[24]	*No*	$O(d.n(n+e+logn) + e^2 + m.n)$
TAN[1]	*No*	$O(n^2)$
BEATA [18]	*No*	$O(n^2)$
[11]	*Yes*	$O(n)$
iMESH [5]	*No*	$O(n^2)$
[21]	*No*	$O(f(r+x))$
MTMS[25]	*No*	$O(e.n.s.k+n+\frac{n^2}{s})$
ITAS[7]	*No*	$O(f(r+x))$
HITAS[7]	*No*	$O(f(r+x))$
GAP-E [15]	*No*	$O(t.n)$
BPSO[3]	*No*	$O(f.x)$
MBPSO[3]	*No*	$O(f.x)$

Table 2: Computational Complexity And Robustness of Role Assignment Algorithms.

Algorithm	Robustness	Computation complexity
MRGAP [13]	No	$O(m.2^n)$
Greedy [13]	No	$O(m.n\,(m+logn))$
SLAM [2]	No	$O(n^2)$
RRAS[9]	Yes	$O(n)$
RBASH[17]	No	$O(n^3)$
INFRA[14]	No	$O(n^2+D.n+m.n)$
DLMA[23]	No	$O(n^2)$
Centralized [12]	No	$O(n^2)$
Distributed [12]	No	$O(n)$

3.2 Robustness:

Robustness is the ability of the network to function normally during a node failure or communication failure [28]. Static pre-computed algorithms do not facilitate robustness [14]. Multiple counter measures were proposed to detect faulty nodes like reputation calculation [9]. Distributed counting algorithm [11] is an example algorithm proposed to achieve robustness. Optimal frequent role changes may prevent and ensure the lifetime of the nodes are equally distributed. But on incurring node or communication failure, counter measures to rejuvenate the network from the failure is yet to be widely reviewed. Investigation of the presence of dedicated procedure for detecting abnormalities and achieve robustness in the role and task algorithms was done and is tabulated in table1 and 2.

3.3 Communication Complexity:

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Communication paves the way for exchanging messages between nodes in the network. Exchanging more number of messages results in communication overhead and also consumes more energy[4]. Multiple operations like routing, elections, clustering, and negotiations, hike the communication overhead. Finding routes in centralized structure causes less communication overhead for network of a smaller size and it is more for a huge network [12, 5]. Regardless of the size of the network in distributed network communication is between its immediate local neighbours causing less communication. Elections, clustering and negotiation algorithms often uses greedy[21, 24], gossip[23] and contention based algorithms[12] leading to communication overhead in a relatively large network. Optimal repetition frequency of these operations is to be scheduled to have better network life time without comprising the dynamicity of the network. Multiple countermeasures like limiting packet to k-hops[5], on demand reactive role assignments[14] and piggybacking control packets with regular data packets instead of dedicated control packets[4] were proposed to reduce the communication overhead.

Table 3: Communication Complexity Of Role Assignment Algorithms.

Role Assignment Algorithm	Communication Complexity		
	Node	CH	HCH/BS
Greedy[13]	$O(n^2)$	$O(n^2)$	$O(n^2)$
MRGAP[13]	$O(1)$	$O(n)$	$O(n)$
RRAS[9]	$O(n)$	$O(n)$	$O(n)$
RBASH[17]	$O(n)$	$O(n)$	$O(n)$
INFRA[14]	$O(n^2)$	$O(n^2)$	$O(n)$
DLMA[23]	$O(n)$	$O(n)$	$O(n)$
Centralized[12]	$O(n^2)$	$O(n^2)$	$O(n^2)$
Distributed[12]	$O(n^2)$	$O(n^2)$	$O(n)$
SLAM[2]	$O(n^2)$	$O(n^2)$	$O(n^2)$

Tables 3 and 4 tabulate the communication complexity of role and task assignment schemes respectively. The number of negotiation messages involved during a reorganization phase of task / role assignment scheme with constant cluster size of 20, 100 and 1000 were calculated theoretically and is tabulated in tables 5 and 6.

Table 4: Communication Complexity Of Task Assignment Algorithms.

Task Assignment Algorithm	Communication Complexity		
	Node	CH	HCH/BS
TAN[1]	$O(n)$	$O(n)$	$O(n)$
BEATA[18]	$O(n)$	$O(n)$	$O(n)$
[11]	$O(n^2)$	$O(n^2)$	$O(n)$
[5]	$O(n.k)$	$O(n.k)$	$O(n)$
[25]	$O(n^2)$	$O(n^2)$	$O(n^2)$
[21]	$O(n^2)$	$O(n^2)$	$O(n^2)$
ITAS [7]	$O(n^2)$	$O(n^2)$	$O(n^2)$
HITAS [7]	$O(n^2)$	$O(n^2)$	$O(n^2)$
GAP-E [15]	$O(n^2)$	$O(n^2)$	$O(n)$
EBTA[24]	$O(n)$	$O(n)$	$O(n)$
MBPSO[3]	$O(1)$	$O(n)$	$O(n)$
BPSO[3]	$O(n^2)$	$O(n^2)$	$O(n^2)$

Network life time is the maximum time between start of the network to the time of failure of the first node due to energy depletion [7]. Assigning roles and tasks in an optimal way to balance workload in WSN would ensure better life time. Some algorithms employed DVS to reduce the voltage levels to peripherals of a node resulting in better life time. Reactive algorithms achieve better network life time than proactive algorithm [14]. Other factors influencing network life time are communication overhead, computational complexities and the frequency of the algorithms. These factors are directly proportional to energy consumption and thus impacting the overall network life time. Optimal allocation of these factors would ensure better life time.

Tables 5 and 6 tabulate the expected life expectancy of various nodes taken up by the node[31]. Network lifetime could be rendered to be maximized by permitting periodic role changes. Tables 5 and 6 also tabulate energy consumed by various types of nodes on using task assignment and role assignment respectively. Energy consumption for negotiation was calculated based on the number of negotiation messages, message size and communication energy. Maximum pay load was taken as 125 bytes[1]. Transmission and reception energy requirement is assumed to be 50 nJ/bit[31].

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Table 5: Energy Consumption Life And Expectancy Of Nodes For Various Task Assignment Algorithms.

Task Assignment Algorithm	Node Type	Negotiation Messages	Cluster Size					
			20		100		1000	
			Energy consumed (μJ)	Life expectancy	Energy consumed (μJ)	Life expectancy	Energy consumed (μJ)	Life expectancy
TAN[1]	Node	$4n + 2$	4100	High	20100	High	200100	High
	CH	$4n + 2$	4100	High	20100	High	200100	High
BEATA [18]	Node	$n + 1$	1050	High	5050	High	50050	High
	CH	$2n - 1$	1950	High	9950	High	99950	High
	HCH/BS	$2n - 2$	1900	High	9900	High	99900	High
[11]	Node	$2n^2 + 4n + 2$	42100	Low	1020100	Low	100200100	Low
	CH	$2n^2 + 4n + 2$	42100	Low	1020100	Low	100200100	Low
iMesh [5]	Node	$n(k + 2) + 2$	7100	Medium	35100	Medium	350100	Medium
	CH	$n(k + 3) - 1$	7950	Medium	39950	Medium	399950	Medium
[25]	Node	$n^2 + 2n + 1$	22050	Low	510050	Low	50100050	Low
	CH	$n^2 + 3n - 1$	22950	Low	514950	Low	50149950	Low
	HCH/BS	$n^2 + 3n - 2$	22900	Low	514900	Low	50149900	Low
[21]	Node	$n^2 + 2n + 1$	22050	Low	510050	Low	50100050	Low
	CH	$n^2 + 3n - 1$	22950	Low	514950	Low	50149950	Low
	HCH/BS	$n^2 + 3n - 2$	22900	Low	514900	Low	50149900	Low
ITAS [7]	Node	$n^2 + 2n + 1$	22050	Low	510050	Low	50100050	Low
	CH	$n^2 + 3n - 1$	22950	Low	514950	Low	50149950	Low
	HCH/BS	$n^2 + 3n - 2$	22900	Low	514900	Low	50149900	Low
HITAS[7]	Node	$n^2 + 2n + 1$	22050	Low	510050	Low	50100050	Low
	CH	$n^2 + 3n - 1$	22950	Low	514950	Low	50149950	Low
	HCH/BS	$n^2 + 3n - 2$	22900	Low	514900	Low	50149900	Low
GAP-E [15]	Node	$n^2 + 2n + 1$	22050	Low	510050	Low	50100050	Low
	CH	$n^2 + 3n - 1$	22950	Low	514950	Low	50149950	Low
	HCH/BS	$n^2 + 3n - 2$	22900	Low	514900	Low	50149900	Low
EBTA [24]	Node	$n + 1$	1050	High	5050	High	50050	High
	CH	$2n - 1$	1950	High	9950	High	99950	High
	HCH/BS	$2n - 2$	1900	High	9900	High	99900	High
MBPSO [3]	Node	$n^2 + 2n + 1$	22050	Low	510050	Low	50100050	Low
	CH	$n^2 + 3n - 1$	22950	Low	514950	Low	50149950	Low
	HCH/BS	$n^2 + 3n - 2$	22900	Low	514900	Low	50149900	Low
Greedy [13]	Node	$n^2 + 2n + 1$	22050	Low	510050	Low	50100050	Low
	CH	$n^2 + 3n - 1$	22950	Low	514950	Low	50149950	Low
	HCH/BS	$n^2 + 3n - 2$	22900	Low	514900	Low	50149900	Low
MRGAP [13]	Node	$2n^2 + 4n + 1$	42100	Low	1020100	Low	100200100	Low
	CH	$2n^2 + 4n + 1$	42100	Low	1020100	Low	100200100	Low

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Table 6: Energy Consumption And Life Expectancy Of Nodes For Various Role Assignment Algorithms.

Algorithm	Node Type	Negotiation Messages	Cluster Size					
			20		100		1000	
			Energy consumed (μJ)	Life expectancy	Energy consumed (μJ)	Life expectancy	Energy consumed (μJ)	Life expectancy
RRAS [9]	Node	$n+1$	1050	High	5050	High	50050	High
	CH	$2n-1$	1950	High	9950	High	99950	High
	HCH/BS	$2n-2$	1900	High	9900	High	99900	High
RBASH [17]	Node	$n+1$	1050	High	5050	High	50050	High
	CH	$2n-1$	1950	High	9950	High	99950	High
	HCH/BS	$2n-2$	1900	Low	9900	Low	99900	Low
INFRA [14]	Node	$2n^2+4n+2$	42100	Low	1020100	Low	100200100	Low
	CH	$2n^2+4n+2$	42100	Low	1020100	Low	100200100	Low
DLMA [23]	Node	$4n+2$	4100	High	20100	High	200100	High
	CH	$4n+2$	4100	High	20100	High	200100	High
Centralized [12]	Node	$2n^2+4n+2$	42100	Low	1020100	Low	100200100	Low
	CH	$2n^2+4n+2$	42100	Low	1020100	Low	100200100	Low
	HCH/BS	$2n^2+4n+2$	42100	Low	1020100	Low	100200100	Low
Distributed [12]	Node	$2n^2+4n+2$	42100	Low	1020100	Low	100200100	Low
	CH	$2n^2+4n+2$	42100	Low	1020100	Low	100200100	Low
SLAM [2]	Node	n^2+2n+1	22050	Low	510050	Low	50100050	Low
	CH	n^2+3n-1	22950	Low	514950	Low	50149950	Low
	HCH/BS	n^2+3n-2	22900	Low	514900	Low	50149900	Low

4. CONCLUSION

Task and role assignment enhances the overall life time and performance of the network. We have analyzed and compared various role and task assignment protocols. It is clearly evident from the literature that most of the role and task assignment schemes were designed for legacy sensors and many vital QoS parameters were not considered. Usage of legacy role and task assignment protocols would render the network to be underutilized in term of overall performances. Lifetime and performance could further be enhanced by proposing new task and role assignment schemes that considers multifunctional node and all QoS parameters into consideration. Our future work is to propose an efficient dynamic robust role and task assignment algorithm that addresses the need of the both legacy and modern era of sensor network in consideration with all QoS parameters.

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