Survey of Wireless Sensor Network based on Power Consumption and Data Aggregation

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Abstract: - Wireless sensor network (WSN), as one of the best emerging technologies of the 21st century, has started to develop at an accelerating pace in the past ten years. A lot of research has been done to improve it in various aspects, including its architecture, contract operating systems, routing protocols, data collection and merging, positioning mechanism, time synchronization, etc. Moreover, large numbers of promising applications have emerged and deployed in various geographies such as infrastructure protection, scientific exploration, military surveillance, traffic control and control, mining security and shipping, environmental protection, object tracking, military affairs, etc. With the conveniences provided by the WSN, it has affected our lives and changed greatly in many ways. However, there are still many problems plaguing the WSN. These include low reliability of wireless communication systems, limited available power, failure of nodes, etc. A WSN is an important way to study and interact with the physical world. A sensor network usually consists of a large number of small sensor nodes. Each sensing node has one or more sensing components for sensing ambient conditions (temperature, humidity, pressure) and a processing and communicating component to perform some simple operation on the data and communicate with its neighboring nodes. Sensor nodes are usually deployed extensively on a large scale and communicate with each other via wireless links. Control nodes process data collected from sensor nodes, collect control commands from sensor nodes, and connect the network to a traditional wired network. Sensor nodes are usually spread randomly, and then form a sensor network in a way that is customized to carry out specific tasks. There is usually no support for sensor network infrastructure. This paper first focuses on providing a survey of traditional WSN and then provides a detailed discussion based on Power Consumption and Data Aggregation.

Key Words: — *Wireless sensor network, WSNs, Data Aggregation, power consumption.*

I. INTRODUCTION

Wireless sensor networks (WSNs) provide a way for organizations to associating the physical and information worlds by efficiently assembling wireless sensors that connect to central software platforms. WSN is a wireless network that consists of base stations and numbers of nodes (wireless sensors). Wireless sensor networks can be used to monitor a set of physical and process parameters, such as sound, smart traffics, temperature, weather forecasting, light, vibration, emergency response, surveillance, commercial, volcanic earthquakes prediction and process information [1-3]. In addition to monitoring these physical parameters, wireless sensor networks are designed to provide data transfer. As shown in the figure.2.

This flexibility enables wireless sensor networks to obtain data from a broad range of sensors to create a comprehensive picture of an area. A wireless sensor network is more cost effective than devices that require a wired connection because it does not require installation of cabling or cabling channels. For example, the 'Sensoroin' Sensor Network Management Platform provides an affordable way to manage hardware, software and cyber threats in wireless sensor networks with near real time visibility of network status through monitor station applications.

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Transmission capabilities are essential components of wireless sensor networks because they allow the sensors connected in the network to communicate with each other and with central nodes. Wireless sensor networks provide the flexibility to adapt to a wide range of environments. This flexibility allows users to customize their network according to the buildings and outdoor area they have determined necessary. For example, wireless sensor networks can be designed for applications such as product delivery, perimeter defense, chemical or radiation detection, temperature monitoring, sound and vibration monitoring.

Wireless sensor networks are typically categorized by their application environments. The three main categories include indoor/outdoor, in-building and onsite/off-site.

For radio communication networks, the structure of a wireless sensor networks includes various topologies like the ones given below.

- Star Topology.
- Tree Topology.
- Mesh Topology.

Star topology is a communication topology, where each node connects directly to a gateway. A single gateway can send or receive a message to several remote nodes. In instar topologies, the nodes are not permitted to send messages to each other. This allows low-latency communications between the remote node and the gateway (base station). Due to its dependency on a single node to manage the network, the gateway must be within the radio transmission range of all the individual nodes. The advantage includes the ability to keep the remote nodes' power consumption to a minimum and simply under control. The size of the network depends on the number of connections made to the hub. And the tree topology is also called as a cascaded star topology. In tree topologies, each node connects to a node that is placed higher in the tree, and then to the gateway. The main advantage of the tree topology is that the expansion of a network can be easily possible, and also error detection becomes easy. The disadvantage with this network is that it relies heavily on the bus cable; if it breaks, all the network will collapse. The last topology is the Mesh topologies that allow transmission of data from one node to another, which is within its radio transmission range. If a node wants to send a message to another node, which is out of the radio communication range, it needs an intermediate node to forward the message to the desired node. The advantage of this mesh topology includes easy isolation and detection of faults in the network. The disadvantage is that the network is large and requires huge investment. Figure.1. show the Wireless Sensor Network (WSNs) Topologies.

The classification of wireless sensor networks can be done based on the application but its characteristics mainly change based on the type. Generally, WSNs are classified into different categories as the following.

- Static & Mobile.
- Deterministic & Nondeterministic.
- Single Base Station & Multi Base Station.
- Static Base Station & Mobile Base Station.
- Single-hop & Multi-hop Wireless Sensor Networks.
- Self-Reconfigurable & Non-Self Configurable.
- Homogeneous & Heterogeneous.

The rest of this paper is organized as follows: Section 2 reviews the power consumption for wireless sensor network. The power of stack protocol is introduced in Section 3. Section 4 presents the data aggregation for wireless sensor network. The conclusion in the last section was presented.

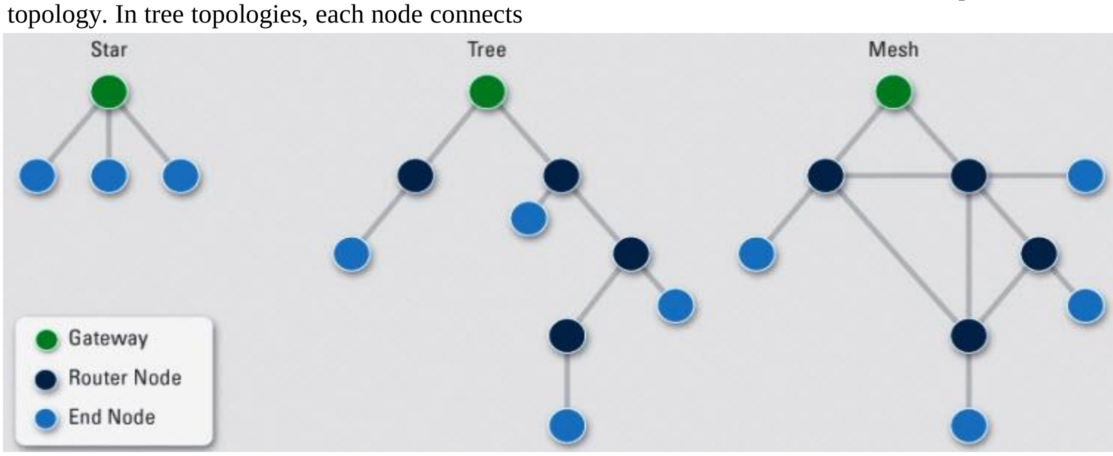

Fig.1. WSNs Topologies.

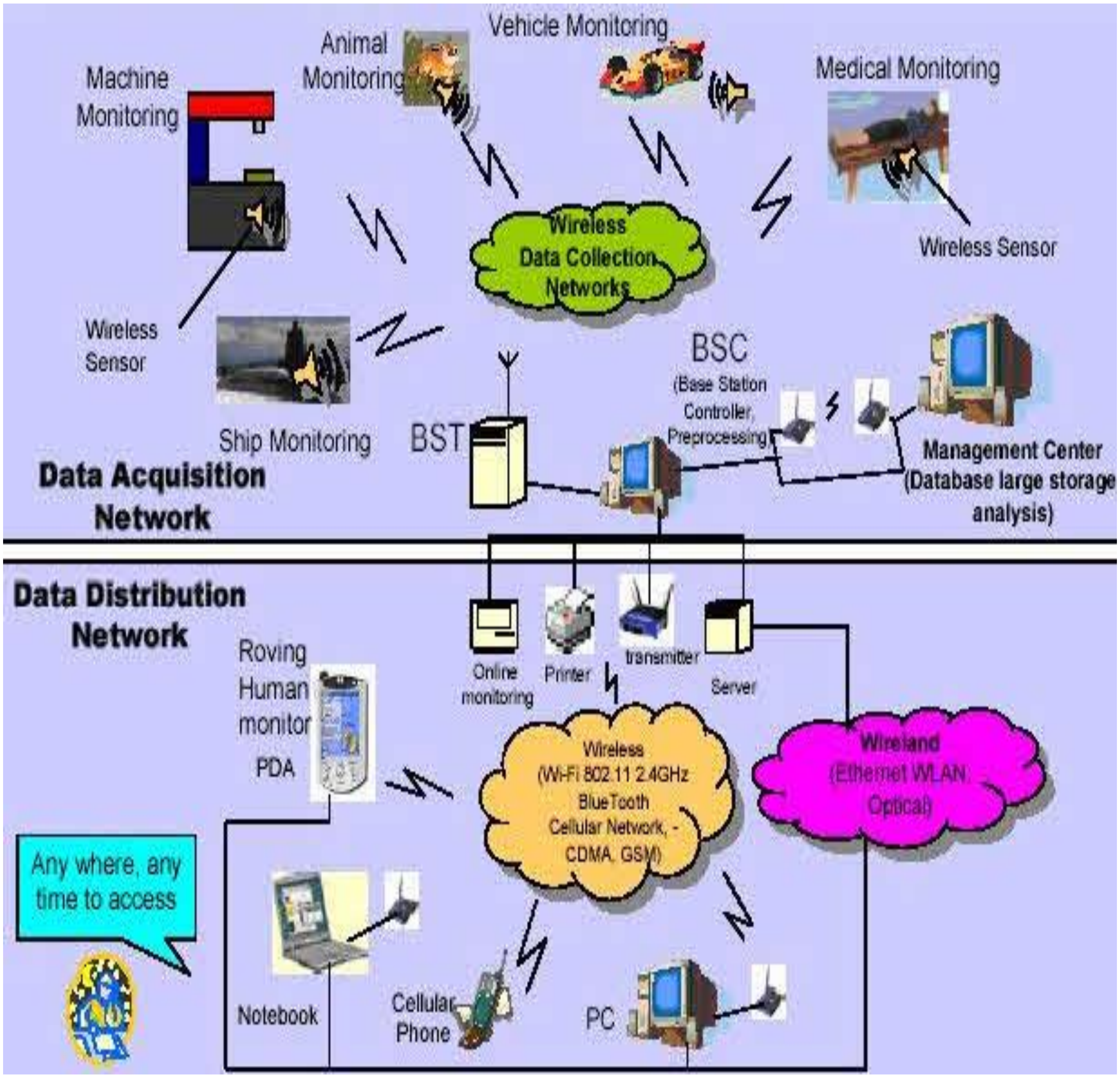

Fig.2. WSNs.

II. POWER CONSUMPTION

Wireless sensor network (WSNs) typically consists of a set of sensing devices which collaborate to collect data from an area, these devices in general divided into two types, the first one is a sink node and the second type is a sensor nodes Which are usually in large numbers each of which gathers information from its vicinity and delivers collected data to the sink node for further processing in a possibly multi-hop fashion. The sensor nodes usually operate with batteries and are often deployed into a harsh environment. Once deployed, it is hard or even impossible to recharge or replace the batteries of the sensor nodes. Therefore, the limited energy available at the sensors makes the network lifetime one of the most critical issues in the design of WSNs. An analytical lifetime analysis can significantly help the network design step. For example, if the analysis takes into account the effects of different network parameters (e.g., initial energy of sensors, network density, sensors transmission range, etc.), these parameters can in turn be adjusted to assure a desired lifetime by the network.

The network lifetime is usually defined as the time until the first node fails because of energy depletion [4], [5]. Due to the multi-hop routing from the sensor nodes to the sink, the sensor nodes close to the sink usually are the most burdened with relaying data from distant nodes. The traffic imbalance can cause early energy depletion for the nodes near the sink, creating an "energy hole" around the sink. The result may be an early disconnection of the sink from the remaining sensor nodes, which may still have plenty of energy [6], [7], [8]. Extending the network lifetime is a critical requirement for a WSN.

Owing to the significance of the power consumption and lifetime in wireless sensor network, there has been considerable research on the lifetime analysis of WSNs under various setups. For example, see [9], [10], [11], [12] and the references therein.

In [11]. It is assumed that a set of sensors that are more powerful are outstretched in the area which act as super nodes that name cluster head (chs). All communications initiated from sensors to super nodes or from super nodes to the data sink are assumed to be done in a single-hop mode. Assuming that the network it works around the clock (clock driven), the average consumed energy by each type of nodes is found and as a consequence the expected network lifetime is obtained. The authors also discuss efficient energy distribution over each type of nodes and find the optimal number of clusters via simulation.

In [13], the researchers suggest a work structure of improving the lifetime of the wireless sensor network by taking advantage of not only sink mobility but also application delay tolerance. The resulting model is called DT_MSM delay tolerant mobile sink model (delay tolerant mobile sink model). The delay tolerant mobile sink model is suitable to those applications where some amount of delay in data delivery to the sink node is permitted. The sensor nodes may delay the transmission of the collected data and wait for the mobile sink node to arrive at the location most favorable for improving the lifetime of wireless sensor network. However, finding an efficient algorithm for delay tolerant mobile sink model is not the focus of [13]. Figure 3 shown the graph of the delay tolerant mobile sink model (DT_MSE).

The researchers studied in [14] a basic communication link where a sensor node with wireless power transfer (WPT) capabilities communicates with a single destination (SD). Specifically, the node (sensor node) is booster with a capacitor, which is charged via radio frequency (RF) radiation by a specification energy source. When the capacitor is charged, the node transmits status updates that containing the most recent information concerning parameters of interest by using all the energy stored.

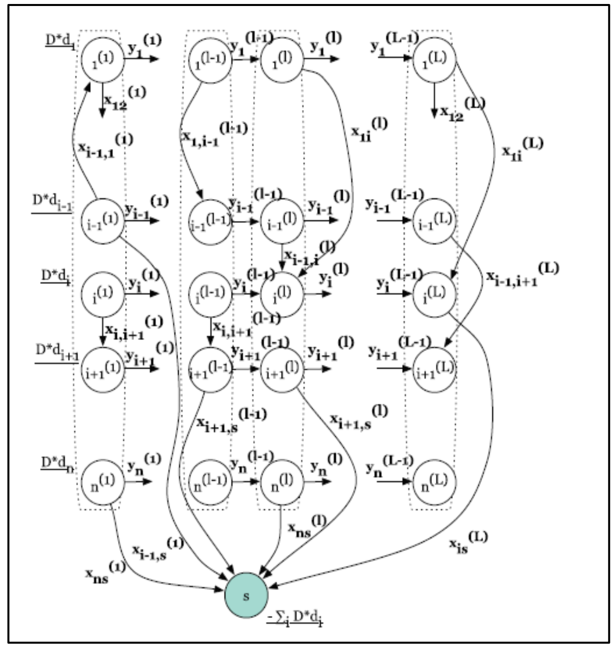

Fig.3. Graph of the delay tolerant mobile sink model [13].

This online transmission policy does not require complicated energy management decisions for example, energy depended thresholds, and is appropriate for wireless power transfer low power and low complexity devices. Investigating the newest of the received information and providing simple closed form expressions for the average of age of information (AoI), which depend on the size of the capacitor. The design of the system leads an interesting tradeoff a small capacitor is charged quickly and thus new updates are sent more frequently to minimize the age of information, on the other hand, a larger capacitor increases the transmit power and boosts the successful decoding. Compute the optimal value of the capacitor by using solving a one dimensional optimization (ODO) problem.

It is worth noting that the network topology and the transmission policy considered are inspired by commercial battery-free WPT products, Power cast [15]; these devices are booster with super capacitors that deliver high power bursts when charged. Although our analysis refers to a simplistic system model, the derived theoretical results can serve as performance bounds (guidelines) for practical implementations. Figure 4 showing the average age of information versus the capacitor's size B for different values of P and d, and figure 5 shows the minimum average age of information versus P for different spectral efficiencies and distances.

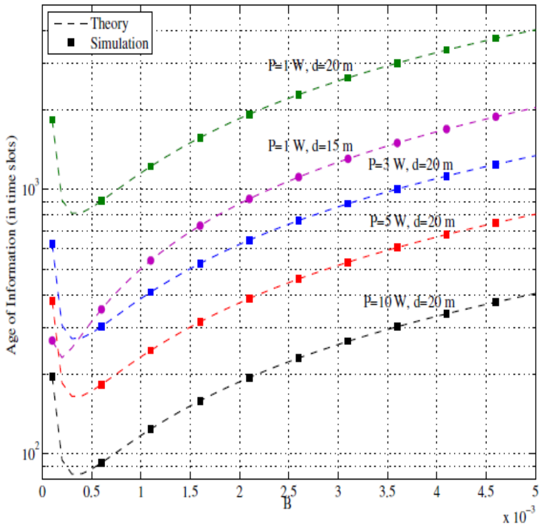

Fig.4. Average AoI versus capacitor's size B for P = f1; 3; 5; 10g Watt [14].

The Work in [16] focuses on the energy consumption and end-to-end delay of QoS based clustered networks where the computationally- and energy intensive tasks, for example, cluster formations and routing, are left for high-power base stations. First, the authors propose a dynamic QoS based clustering protocol and then provide its performance analysis in terms of the average energy consumption and expected network lifetime. For the sake of the energy efficiency, it is assumed that the cluster head role rotates among different nodes within a cluster. Random networks are not considered in this study.

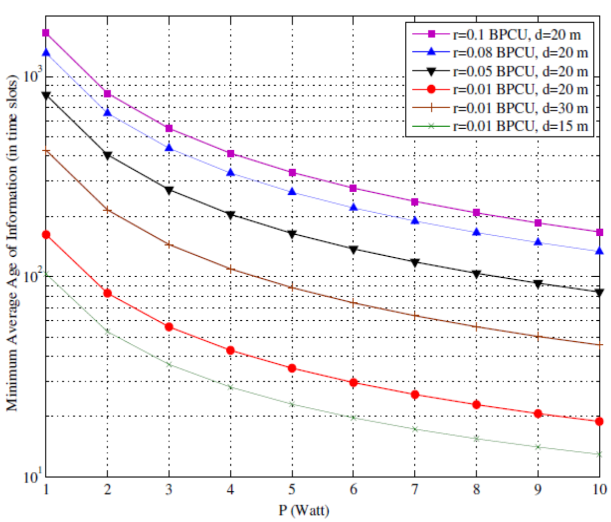

Fig.5. Minimum Average AoI versus P for r = f0:01; 0:05; 0:08; 0:1g BPCU [14].

III. Power Of Stack Protocol

The sensor nodes used the stack protocol as shown in Figure 6. Many research has been done to design schemes for power conservation and power management in sensor nodes on all layers of stack protocol, as studied in subsequent sections. Performance of such schemes can be evaluated through simulation tools for example "PAWiS" [17]. The power consumption in stack protocol layers in the following sections are:

- Physical Layer power
- Data Link Layer power
- Network Layer power
- Transport Layer power
- Application Layer power

3.1 Physical Layer power

A significant number physical layer regulation schemes diminish those radio-transceiver control utilization by decreasing transmission time [18]. Yet all the transmission vitality could additionally make lessened by bringing down transmission force What's more expanding transmission span [19]. Transmission vitality doesn't monotonically diminishing similarly as transmission time expands.

Transmission vitality might increment the point when transmission time surpasses some edge esteem. Higher regulation levels might make doubtful in WSNs in any case for peak-throughput, higher regulation levels need aid required. Additional vitality could be saved toward rapidly adopting those regulation level as stated by immediate movement load, known as regulation scaling. Different frequency-shift keying (M-FSK) will be additional vitality productive over other M-ary or double regulation schemes to short range, low obligation correspondence systems, similar to WSNs [20].

A factor that effects on lifetime of battery is the discharge rate of current. All battery has a specific discharge rate value specified by the manufacturer. Drawing higher current than specified results in reduced the life time of battery because the active ingredients diffusion rate through the electrolyte falls behind their consumption rate at electrodes. If a high discharge rate is maintained, the battery can end life time. The battery can recover to a certain extent from high discharge rate effects, through a phenomenon known as battery relaxation, in which the amount of current drawn from the battery is reduced or cut off [21].

Batteries have approximately twice as long a lifetime, if they are discharged in short bursts with significant off time, rather than in continuous operation [22]. Therefore, battery lifetime is extended when the sensor node operates by frequently oscillating between an active state and inactive state.

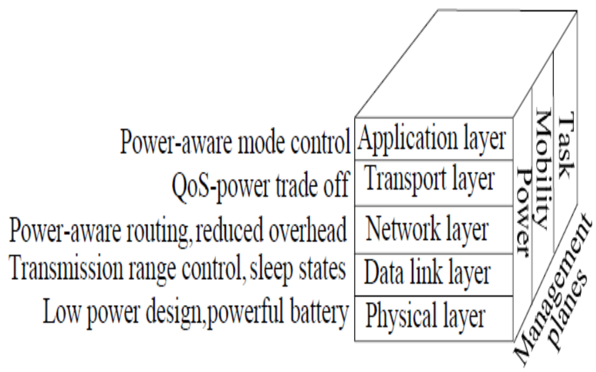

Fig.6: layer of stack protocol sensor networks.

3.2 Data Link Layer power

The data-link layer consist of error control (EC) and Medium Access Control (MAC) protocols. MAC protocol in a self-organizing wireless sensor network (WSN) creates network infrastructure by using determine suitable communication channels, and shares available communication media among sensor nodes. Since transmission is the most power consuming task in a sensor nodes, MAC-protocols should be duly designed to offer power saving by cutting down power inefficient access to minimum. A sensor nodes wastes a great amount of power due to:

- Idle-listening of channel.
- Packet collision.
- Overhead of control packets.
- Overhearing.

In idle-listening and collision, the node continuously consumes power in retransmission and sensing channels respectively. Therefore, power efficient MAC protocol must avoid collision, overhearing, overhead of control packets, and idle-listening. Some of the data link layer protocols are enlisted in Table 1.

The transmission-Power-Control (TPC) mechanism can be used to control traffic transmission performance on a network and thus, conserves power. Transmission power determines transmission range and interference caused at other nodes. Properties of power adjusted transmissions have been investigated [23].

Transmission power control protocols can employ fixed TPC (FTPC) or dynamic TPC (DTPC). FTPC improves power consumption up to 16-percent for convergence traffic, when compared with DTPC, but no significant performance improvements for aggregate traffic [24].

3.3 Network Layer power

The network layer is accountable of topology control, layer three making routing decisions and addressing. Depending on node versatility, network can take on (directed, single-hop clustering, multi-hop, or multi-hop clustering transmission schemes), as shown in Figure 7. Type of transmission scheme supported by protocol depends upon its functionality. In Table 2 Some of the network layer protocols are enlisted.

3.4 Transport Layer power

The transport layer is wanted for end-to-end delivery. It may not be wanted in wireless sensor network because of hop-by-hop communication but may be needed for security reasons. Protocols on the transport layer of the sensor network protocol stack may be connectionless to avoid costly acknowledgement mechanism because of power constraint.

3.5 Application Layer power

The wireless sensor network are applications specific and therefore, protocols lying on application layer vary with application demands. Sensor management protocol (SMP) makes software and hardware of lower layers transparent to management activities.

Sensor query and data dissemination protocols provide user applications with interfaces to issue queries, respond to queries and collect incoming replies.

In interest dissemination protocols, the user sends their interest to nodes. In data advertisement protocols, the sensor node advertises available data to user nodes.

Table.1. Data link layer schemes

Scheme	Description
Centralized MAC schemes	
Hybrid TDMA/ FDMA	Based protocols calculate optimum number of channels and are more energy efficient than TDMA or FDMA.
Sensor MAC (S-MAC)	Avoids idle listening, overhearing, and collision. Consumes extra power during fixed active period when there is no traffic load.
Timeout MAC (T-MAC)	For variable payloads, it uses less energy than S-MAC because of adaptive duty cycles. It suffers from packet collision.
PAMAS	Power saving medium access protocol (PAMAS) reduces collisions, avoid overhearing and use transmit control messages for energy saving.
Sinha' 2001 [24]	Renders desired energy-quality scalability at cost of latency and sensing accuracy.
Arisha' 2002 [25]	Techniques do not scale as network size increases.
SIFT[26]	Provides energy-latency trade-offs. It suffers from idle-listening and overhearing.
PAPSM	Phase announcement power save mechanism (PAPSM) uses short communication window that limits data transmission or increases transmission time.
SPAN [27]	Uses adaptive scheduling strategy based upon local information and is therefore, scalable.
DMAC [28]	Solves data forwarding interruption, channel contention, and collisions problem. It adaptively adjusts node duty cycles according to traffic load. It provides reduced latency while ensuring high data reliability.
Pattern MAC (P-MAC)	Adopts sleep/wakeup schedule based upon its own and its neighbour traffic. It consumes extra energy to maintain traffic pattern information.
PCS-MAC [29]	Power controlled sensor MAC (PCS-MAC) avoids collision and overhearing. It maintains schedule and minimum power level required to communicate with each neighbour node.
Udenz' 2007 [30]	Optimizes sleep schedule by scheduling network events.
ESR-MAC [31]	Efficient slot reservation MAC protocol preserves collision free transmission. It provides efficient energy saving than S-MAC and T-MAC because of efficient packet transmission. It is more effective in data gathering WSN.
Fixed LPL schemes	
B-MAC	Suffers from idle-listening.
wise MAC	Trade-off exists between energy and transmission latency.
Z-MAC [32]	Combines strength of both CSMA and TDMA. At higher transmission rate, it performs better than B-MAC due to more efficient contention resolution.
Pianegiani' 2008	Uses signals classification to reduce amount of transmitted data based upon computational latency overhead [33].
Dynamic LPL schemes	
Boost-MAC	Adjusts preamble immediately after single idle or busy channel observation.
X-MAC	Uses short preamble that reduces latency and energy consumption.
Hohlt' 2004 [34]	Proposed distributed techniques introduce significant overhead.
Transmission power control (TPC) algorithms	
Clustering [35]	Optimizes transmit power level in non-homogeneously distributed network.
MSC [36]	Integrates transmitted signal power control with received information quality.
DTPC [21]	Improves throughput and power consumption of multi-hop WSN by adjusting radio transmission power until it hears desired number of neighbours. It is useful in combination with LPL that implements low duty cycling.

Table.2. Network layer protocols

Protocol	Description
Data centric routing protocols	
Flooding	Suffers from implosion, resource blindness, and overlapping.
Gossiping	Eliminates the problem of implosion but introduces propagation delay and more resource utilization. It utilizes less power compared with flooding.
Directed diffusion	Not suitable for applications where information is required upon a periodic basis.
SPIN [48]	Sensor protocol for information via negotiation overcomes problem of implosion, overlap, and resource blindness. It is not suitable for applications where information is required upon a periodic basis.
Rumour routing	Instead of flooding queries, events are flood when the number of events is less than the number of queries.
EPAS, HEPAS [49]	Energy efficient protocol for aggregator selection (EPAS) and HEPAS calculates number of aggregators needed to minimize amount of total energy consumed in network.
Hierarchical routing protocols	
Low energy adaptive clustering hierarchy (Leach)	Some overhead is produced in periodically choosing heads but balances the communication load upon each head. Since it is two-hop routing protocol, it cannot be deployed for a huge geographical area. Power usage per node for Leach is less than the power required in flooding, gossiping, and GBR [50].
Static clustering	Energy can be saved by processing data locally instead of sending it back to base-station.
Pegasis	Power efficient gathering in sensor information systems (Pegasis) is a chain based clustering protocol.
BCDCP [51]	Balances load on each cluster and provide better energy savings compared with Leach and Pegasis.
Gradient based routing (GBR)	Utilizes neighbour's hop-count information to make a packet forwarding decision. It works better compared with gossiping [50].
TEEN, APTEEN	Used in time critical applications. Cluster heads send only significantly changed data to the nodes. Formation of cluster heads is an overhead. In APTEEN, data is also sent periodically.
Ad-hoc on demand distance vector (AODV), CTR	Find shortest path and consume least power but they may limit network lifetime because of unawareness of node's energy level during communication. In cluster tree routing (CTR), cluster heads are fixed during network lifetime and thus, die quickly.
EADV [52]	Makes use of computational and implementation simplicity as compared to AODV and DSDV.
Abusaimeh'2009 [53], Madani'2008 [54]	Role of cluster heads is distributed among nodes based upon the remaining energy of the node.
Location based routing protocols/ algorithms	
Direct	Quicker power supply depletion at the nodes far away from the base-station compared with nodes closer to the base-station.
Minimum transmission energy (MTE) [55]	Node does not select another neighbouring node for relaying its messages until its relaying node's power is depleted. Second, nodes that are closer to the base-station will die soon. Third, nodes furthest away from base-station will live longer because they do not have to relay the messages of other nodes.
e3D [56, 57]	In energy efficient distributed dynamic diffusion (e3D) routing algorithm, each node updates neighbours' information through distance derived from radio signal strength, battery power and load.
TPR [58]	No need of routing table and neighbourhood information.
Topology control protocols/ algorithms	
GAF	Rotates node functionality periodically to ensure fair energy consumption among nodes.
SPAN algorithm	Trade-off exists between topology maintenance and energy conservation
Sparse topology and energy management (STEM)	Increases network lifetime by maintaining network connectivity at a cost of increased latency [59]. This approach is for event based monitoring systems. STEM improves network lifetime, when compared with GAF and SPAN.
ASCENT [60]	Adaptive self-configuring sensor network topologies (ASCENT) conserves energy by allowing only those nodes to remain active that are required to maintain path towards destination.
Slijepcevic' 2001 [61]	Achieves energy saving by using only a subset of stochastically placed sensor nodes at each moment while fully preserving coverage.
MP-SCTC [62]	Makes network strongly connected and minimizes the total amount of power used.

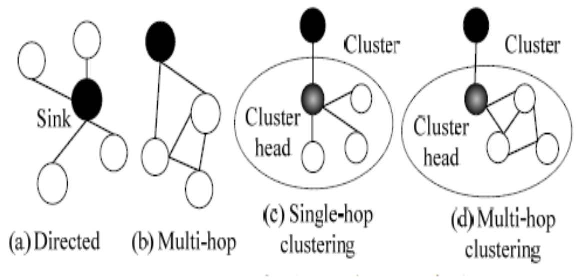

Fig.7. Transmission schemes in WSN.

IV. DATA AGGREGATION

It has been spotted that nodes sensors close to the static sink node deplete energy much faster than others nodes sensors due to the fact that they forward much more data than other sensors. Based on this spottation, many researchers proposed, for example [15]-[24], have proposed to use mobile data collectors to achieve uniform energy consumption.

In such data aggregation scenarios, sensing data is generated continuously (video surveillance for example), in time intervals (ambient temperature monitoring for example), or when events of interest are detected (target detection for example), stored in local buffers, and sent to the mobile data sink when they position at nearby places. [25] And [26] proposed schemes in which mobile data aggregations move along parallel straight lines for data aggregations. .

in reference [27] proposed the researchers a rendezvous design, which objectives to find a set of rendezvous points to be visited by the mobile sink node within a required delay bound, where [28] presented a distributed maximum life-time routing algorithm for sensor nodes network with a mobile base station, and in [29] studied optimal movement of a mobile sink node and proposed a solution that warranties at least [1 – ε] of maximum network life-time, where ε can be arbitrarily small.

Where Zhao in [30] proposed a joint design of mobility-control and SDMA (space-division multiple-access) technique to find the tradeoff between the full utilization of space-division multiple-access for data transmissions and the shortest moving tour of the mobile collector and. while also provided optimization based distributed algorithms to maximize the network utility in mobile data gathering in [31].

The researchers in [32] and [33] proposed a heuristic-algorithm for planning the moving path of mobile collectors and balancing traffic load in the multi-hop network. Where Wang, et al. in [34] used mobile relays to help relieve sensors that are heavily burdened by a high volume of network traffic [35]-[37].

Although aforementioned schemes can greatly save energy by utilizing mobile collectors compared to the relay routing in static networks, none of them has considered renewable energy for sensors. In contrast, our work in this paper explores the performance gain when recharging is possible. It computes the migration tour of the SenCar based on the joint consideration of recharging demand and data gathering performance, and also adapts adjustable system parameters to the up-to-date energy replenishing status to optimize data gathering performance. Figure 6 shows the Architecture of joint mobile energy replenishment and data aggregation while figure 7 shows the Timing of joint mobile energy replenishment and data aggregation.

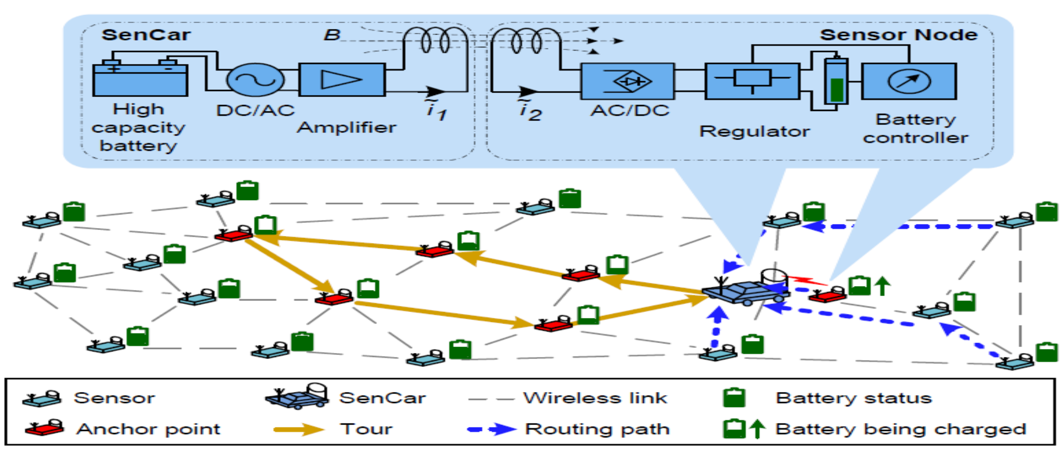

Fig.6. Architecture of joint mobile energy replenishment and data gathering.

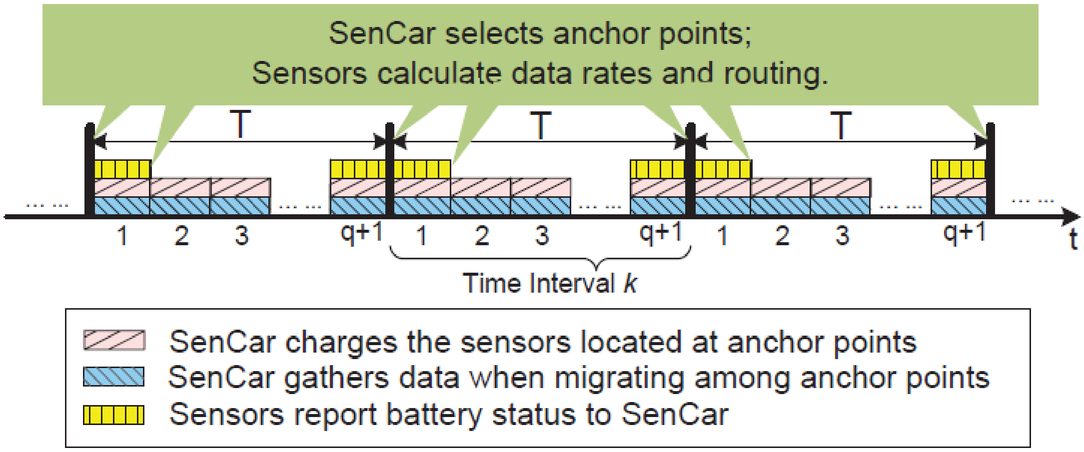

Fig.7. Timing of joint mobile energy replenishment and data gathering.

V. Conclusion

The survey was presented in this paper on traditional wireless sensor network and then provides a detailed discussion around on Power Consumption and Data Aggregation for wireless sensor network by presented the related work for wireless sensor network for various researchers in different fields and showing the important factors in these networks.

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