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A review of localization algorithms based on software defined networking approach in wireless sensor network

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ABSTRACT

Wireless Sensor Network (WSN) localization is an important challenge, because A strong relationship between aggregation sense data and the location of data's origin. Software Defined Networks (SDN) technique is support localization algorithm and take into account all network's limitations and constraints. By making use of global network knowledge provided by SDN controller, the results of previous studies show that considerable improvement in network performance can be achieved. This paper explores the recently proposed localization algorithms and discusses the simulation results for each method used in Software Defined Wireless Sensor Networks (SDWSN) to find the best way to localized nodes with the highest accuracy and lowest energy consumption. This paper also present Software defined networking paradigm and WSNS challenges which solved by SDWSNs.

1. Introduction

Wireless sensor networks (WSNs) have taken a lot of attention in recent years. WSN considered as the fundamental of smart environment, it acts as interface between the real world and smart systems. Sensor nodes have been used in wide applications such as monitoring, tracking and security applications [1]. WSN is a group of distributed and autonomous sensor for monitoring the physical environment [2].

Wireless sensor network is the backbone of Internet of Things (IoT). Under the heterogeneous environment, a large number of sensors are connected together used to aggregate large amount of data. IoT network in the case of a smart city must be scalable with any number of devices and different technology in anytime, and because the wide application areas and difference of technology among the devices, incorporating WSN becomes challenging [3].

Sensor's location awareness has a great interest in many wireless systems. Actually, sensing data without knowing the sensor location is meaningless [4].

In distributed localization the nodes gather the measurement with various methods and determine the distance between neighbors and anchor nodes [5]. Due to different requirements and network constraints, such as battery consumption, computational resources, link technology and radio transmission range, Authors like Junior et al. in [6] proposed a model based on Software Defined Networking (SDN) paradigm, in which a controller have a global view of the network and it has the ability to choose a suitable allocation algorithm, also takes into account when choosing the requirement to be fulfilled, Such as extending the network lifetime, improving processing power of applications or reducing the quantum of data exchanged in the network.

In this paper, we present a comprehensive survey on localization in wireless sensor networks, shows how the centralized nature by using SDN technology improve the performance of network and gain more accuracy results when estimate the position for sensing nodes instead traditional algorithms.

The rest of this paper is organized as follows. In section II, introduce the concept of SDN and its effect on improving the work of WSN. Current methods for localization in software defined wireless sensor networks presented in section III. In section IV we conclude this paper.

2. Background

- Concept of SDN

Software Defined Networking (SDN) is a network paradigm designed to simplify network management and configuration. It decouples network control plane from the underling networking devices (data plane), the data plane became forwarding device with little or no intelligence. The separation provides centralized network intelligence at

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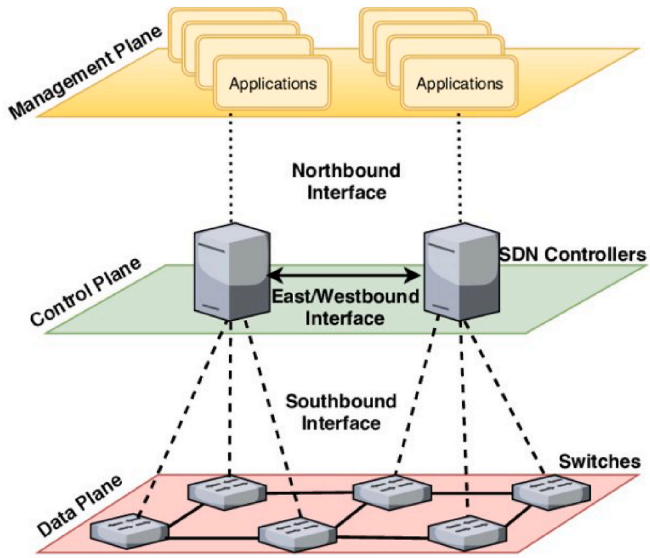

Fig. 1. SDN Architecture adapted from [10].

- ***Data plane*** (infrastructure layer): which consist of network element such as physical devices (switches, routers, wireless access points, etc.) that contract with the network traffic, its handles packet forwarding inside the network, while it's behavior is determined by the control plane. In the SDN terminology these devices are referred to as network *switches* [11,85].
- ***Control plane***: it's a powerful layer in the network who houses the decision made by the controller and provides routing to traffic in the network, it is responsible for the configuration of the forwarding plane. Control-plane functionalities include: Topology discovery and maintenance, Packet route selection, and Path failure mechanisms [12,29–34], different routing protocol such as RIP, OSPF, BGP and EIGRP are run by the control plane [13, 35–39].
- ***Application plane***: lies at the top of the SDN stack, which comprises all the applications that exploit the services provided by the controller in order to execute network-related tasks. Examples of network applications are load balancing, routing, network virtualization, etc. [11,14,40,41].

the controller, which has a global view of the network [7]. The unique characteristic of SDN is that it enables programmability through decoupling of control and data planes, and makes network management much more flexible [8,81].

Authors in [9] propose base station architecture for WSN based on SDN with review of benefits of this technology, they present how SDN can be useful for WSNs implementations in main issues like.

- Using SDN could promise an energy efficient way for sensor management, the global view of the network can minimize the power consumed by different nodes in order to maintain that view locally.
- In the network contains mobile sensors the network topology changes. Subsequently, routing protocol need time to converge. The convergence time can be reducing in case the network managed by centralized SDN controller.
- The most important motives behind SDN was to simplify the network management process and increase the flexibility of sensor network.
- High accuracy location information could be gain by employing a centralized localization algorithm.

SDN architecture consist of 3-layered components connected by multiple application program interfaces (APIs), As shown in figure (1).

Controllers are the brain of SDN architecture, All the intelligence of SDN comes from the controller, it used to extract the information from the devices and give it to the SDN applications in addition to management and the centralized configuration functions [15,80].

With the evolution of SDN paradigm, a set of SDN controllers are developed based on the specific requirements. SDN controller is categorized in centralized, distributed and hybrid controllers. SDN controller classification is shown in Fig. 2.

The communication between the application and control plane is referred to as North Bound Interface (NBI) while communication between the control and the data plane is referred to as South Bound Interface (SBI). In large-scale networks multiple SDN controllers are used, each controller handles a set of data plane devices, These SDN controllers share network information of their respective domains with each other to have a global network view. This information exchange via East/Westbound Interface [42,43,84].

Open Flow is an SDN technology proposed to standardize the way that a controller communicates with network devices. It was proposed to enable researchers to experienced new ideas in production environment. OpenFlow provides a specification to transport the control logic from a switch into the controller. It also defines a protocol for the communication between the switches and the controller [44,83].

2.1. SD-WSN

Software Defined Wireless Sensor Networks (SDWN) Is challenging model because it's a product of merging two models with their complexities and challenges.

The WSN networks are resources constrained it must be able to faces several challenges related with necessitate to be energy awareness Considering sensors power depends on battery and recharge or replace the battery is a difficult task, reliability and scalability issues, And SDN model has its own challenges specially trade-off between sensor functionalities and other network factors such as latency [45,82].

The first attempt to combine SDN and WSN presented in [46], the authors proposed a SDWSN architecture that clearly separates the control plane and the data plane, and also using Sensor OpenFlow (SOF) which is the core component of SD-WSN as a standard communication protocol between the two planes. This model enhanced traffic load balancing as well as reduced the amount of communication overhead. This approach has also reported important improvements in the energy consumption of the system. SOF is based on flow rules. Each forwarding device contains a table of flow rules which the control layer can interact with [45].

Fig. 3 (adapted from [47]) presents the general architecture of SD-WSNs which consists of the following layers: data layer, control layer and application layer.

i) The data layer (infrastructure layer) represented by a set of sensor nodes which sense and forward data through the network based on a set of rules and routing decisions made by the controller within the control plane [45].
ii) The control layer represents the abstraction of routing and decision making processes from the network, it has a global view of the entire network. The centralized control requires a more powerful device than typical sensor nodes to run the control plane. Most of the powerful functions are moved from the sensor node to the controller. With SDWSN, the sensor nodes have only forwarding capabilities when control layer mainly responsible for computing flow table and handling general issue related to network management and control [48].
iii) The application layer includes routing optimization, topology control, simulation and special algorithms [49].

Authors in [50] was used SDWSN in smart Grid WSNs to minimized complexity and power optimization, while [9,51] proposed SDN as a means to smartly manage WSNs to solve some of the difficult problems in WSNs such as energy saving and network management.

Much work has been done in an attempt to find solutions to the most critical WSNs challenges, researchers do the best to optimize energy consumption in SDWSNs [52,53], increase efficiency of network

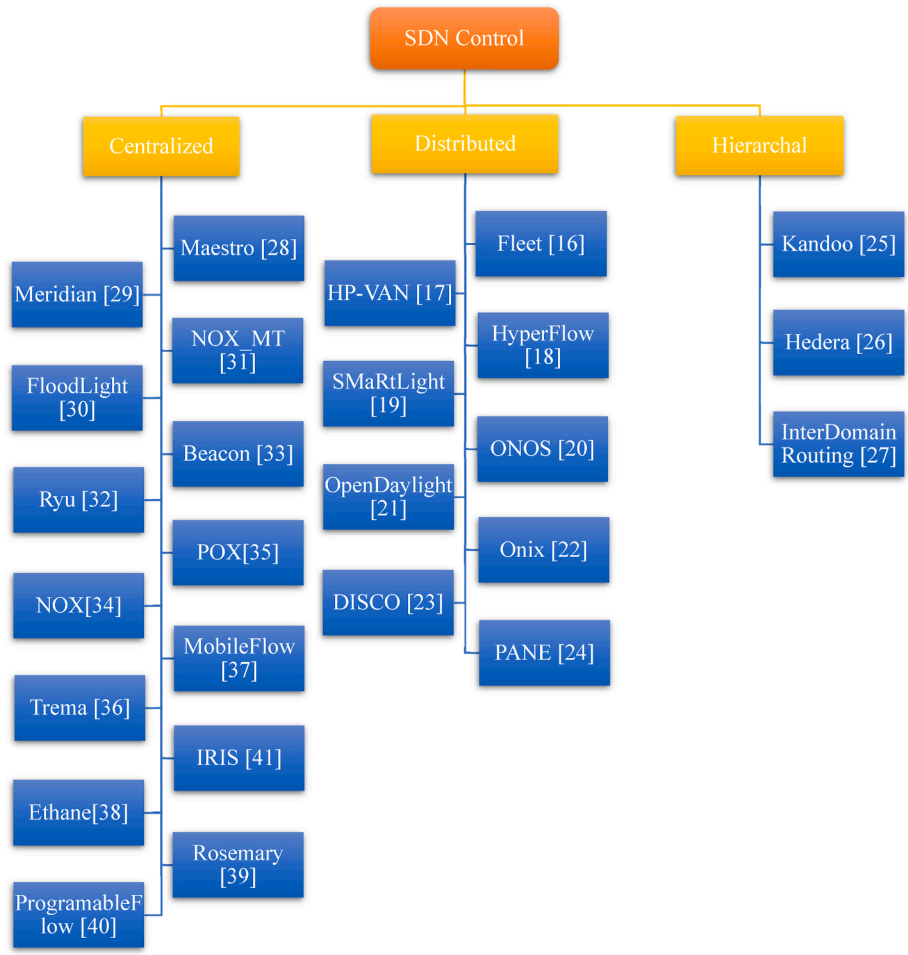

Fig. 2. Sdn controllers classification.

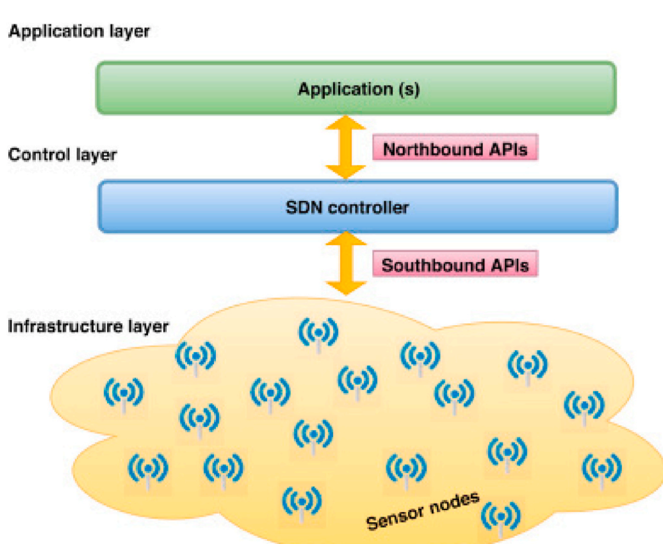

Fig. 3. SDWSN architecture according to [47].

management [8,16–23], improves network scalability such as paper [54] authors performed several experiments in networks up to 289 nodes, the impact of the routing protocol on energy usage [55], improved localization scheme under the network power constraint [56], foster interoperability with other networks [45], improve communication [57] and addressing some security issues [58]. Authors like Letswamtse et al. [59] proposed (SDWSN) strategies for efficient resource management and guaranteed QoS support to get better performance.

Several studies have proposed different types of SDWSN architecture with various features and functionalities. Each architectural Aims to enhance the consistency and reliability of SDWSN as shown below in Table (1).

Due to the centralized nature of the SDN, all the computational operation done in the control plane. This has the benefit of relieving sensor nodes from burden of calculating its own location.

3. Localization

Location information of each node is essential for many applications in wireless sensor networks. Usually, the nodes are randomly deployed in the network zone. It's an important matter to positioning each node using localization techniques [24–28,71].

The question that may come to mind is why don't we simply use Global Positioning System, GPS is appropriate for this task, but it need to consume more energy to run and it is expensive to install on each sensor node, also GPS will not provide accurate localization results in an indoor environment [72].

Depending on the availability of location information of nodes, nodes in WSN can be classified in to: anchor (beacon or references) that its location is known by GPS receiver or by human intervention, unknown nodes (normal nodes or unlocalized nodes) which does not know its own position, and localized node which at some point was

Table 1
Architecture development of software defined wireless sensor network.

Ref	contribution	Characteristics
[60]	flow sensors	It is exploit the OpenFlow technology to address reliability issues.
[61]	SDWN(Software-defined wireless network)	It is considered the first attempt to analyze the opportunities and challenges of applying the SDN paradigm in IEEE 802.15.4 networks.
[62]	Sensor OpenFlow	SD-WSN with Sensor OpenFlow as a solution for WSN-inherent problems
[63]	SDSN(software-defined sensor network)	A new WSN paradigm, which is able to address various application requirements and to discover the communication, computation and sensing resources of WSNs, Sensor nodes in this paradigm can be dynamically reprogrammed for different sensing functions via the over-the-air-programming technique
[64]	Online Algorithm	Using online algorithm to optimized network energy efficiency with much lower rescheduling time and control overhead
[65]	SDCSN(software-defined clustered sensor networks)	Software-Defined Networking (SDN) in wireless sensor networks (WSNs) with a structured and hierarchical management based on the cluster with multiple hosts acting as base stations for the cluster heads and control function to solve some inherent challenges with WSNs
[66]	TinySDN	Proposed TinyOS-based SDN framework that enables multiple controllers within the WSN to reduce the complexity of network configuration and management by distributing tasks between two main components: the SDN controller node, where the control plane is programmed and the SDN-enabled sensor node, which has an SDN switch and an SDN end device
[67]	Distributed control plane Architecture for SDWSNs	Presented architecture with distributed and hierarchical controllers (Spotted SDN controllers architecture), where local controllers use local information to reply to nodes within its area, and a global controller manage the whole network, to reduce control traffic and support flexibility and scalability.
[68]	Soft-WSN	support application-specific requirements of the IoT, authors design a controller, which includes two management policies — device management and network management topology of the network can be modified in run-time to deal with dynamic requirements of IoT.
[69]	SD-WISE	It is a unique architecture, which is a complete software-defined solution for WSNs, it has significant features such as: it supports flexible way to define flows and control the duty cycles to reduce energy consumption, it enables network function virtualization in WSNs which can be applied to implement any networking function, and foster the interplay between hardware and software to support regulation compliant behavior of sensor nodes.
[70]	MC-SDWSN (software-defined mission-critical wireless sensor network)	ensures the availability of mission-critical computing and communication resources on a timely and dependable basis, by centralized computing resource management strategy

unlocalized node but has had its position estimated [73].

Researchers tried to use various distance estimation methods during localization in a SDWSN and because the novelty of localization in this networks there's only small amount work done in this field, some of them have proposed methods to determine the position of the nodes with high accuracy and least energy consumption and others improve that not all the known algorithms in WSNs field are useful and gainful when used in SDWSN as shown in the simulation results in Table (2).

4. Methods of localization in SDWSN

4.1. Gainful methods

- Authors in [74] propose **a localization node selection algorithm:** based on Cramer Rao Lower bound (CRLB), the authors first gain the inter-node distances via single strength (RSS) measurements, second calculate CRLB, after that they implement anchor node selection algorithm based on (CRLB) and finally Euclidean Position estimation by using linear least square algorithm based on selected nodes. The experiment was done in 80 m $\times$ 80 m environment with 50 agent nodes and 22 anchor nodes. Simulation results show that considerable improvement in localization performance can be achieved with proposed SDN based algorithm up to 45% increase in node accuracy with this procedure over randomly selecting anchor nodes for position estimation.
- Zhu et al. in [75] presented **an anchor scheduling scheme** to maximize the life time of the network by reduces the number of active anchors within the network, they propose a centralized anchor scheduling scheme on basis of the software-defined networking (SDN) paradigm, every anchor was designed with a timer which value is determined by controller. The scheme works in two phases: *initial phase* in which an unknown node broadcasts HELLO message to all activate its neighboring anchor nodes, each anchor node sends their own position, type, initial energy, residual energy and rang measurement with unknown nodes to the SDN controller, at this moment the controller builds the routing/flow tables and estimate the position of unknown nodes as its initial position. The second phase is *scheduling phase*, at each time slot unknown node sends a message to the neighboring anchor nodes which are within the range then the anchors send the information to the controller, if the position of the anchor has been stored before, the controller only updates its residual energy and range measurement, otherwise a new table will be constructed for this anchor. Simulation result for 120 m $\times$ 120 m rectangular sensor field with 200 randomly placed anchor nodes and 10 mobile agents move in field show that the scheme reduces the number of active anchor nodes and can slightly decrease the accuracy of localization with big reduction in the energy consumption and therefore increase the network lifetime.

Zhu et al. in [76] presented the same scheme, field and number of anchors proposed in [75] but they raised the number of mobile agents to 20 agents moving in the field to prove that the advantage of the proposed scheme is related to the number of agents. The higher the number of localized agents, the greater the number of active anchors.

- In [77] Zhu et al. proposed **node-selection strategies in non-cooperative and cooperative scenarios** based on the software-defined sensor networks by calculate the analogous Cramer-Rao lower bound (A-CRLB) value for each node, these strategies are applied in both non-cooperative and cooperative localizations. Simulated results showed that the proposed algorithms improved accuracy in localization results in SDSNs and reduced root mean square error (RMSE) in cooperative localization.

In [78] Zhu et al. modify a conventional cooperative localization approach to improved localization performance for IoT WSNs. Authors

Table 2
Methods of localization in SDWSN.

Ref	Method	Environment	No. of nodes	Simulation result
[74]	SDN Node selection algorithm	80 × 80 m	22 anchor nodes 50 agent nodes	45% increase in node accuracy allocation.
[75]	An anchor scheduling scheme	120 × 120 m	200 anchor nodes 10 mobile agent	• Reduce the no. of active anchors • Increases the network lifetime
[76]			200 anchor nodes 20 mobile agent	• Slightly decrease the location accuracy • Great reducing in the energy consumption • In [76] increase the no. of agent meaning increase active anchors
[77]	Node selection in cooperative and non-cooperative localization scenarios.	80 × 80 m	20 anchor nodes no. of agent nodes bigger than the number of anchor nodes depending on various number ratio	• 18% reduce root mean square error (RMSE) • Improve localization accuracy
[78]	Node selection and non-line-of-sight (NLOS) mitigation strategies to modify cooperative localization algorithm	100 × 100 m	13 anchor nodes 50 agents	• Reduce the energy consumption • Improve the localization accuracy in harsh environment
[79]	Trilateration, Maximum likelihood estimation and the Linear Least Square localization algorithm	10 m around the control node	1 control node 3 anchor nodes 6 unknown nodes	• The same result can be achieved if the same input data is used using the 3 algorithms regardless if they were implemented in the control plane or in the data plane. • unnecessary energy consumption

proposed node selection algorithm to reduce the energy consumption of the network, and proposed non-line-of-sight (NLOS) mitigation algorithm to increase the localization accuracy.

4.2. Un gainful methods

Cloete et al. in [79] improve that it is not always better to do the computational requirement of localization into the control-plane, they are compares and implements three localization estimation algorithms in SDWSNs: **Trilateration, Maximum likelihood estimation** and **the Linear Least Square Localization algorithm** in both the control plane and data plane using IT-SDN in a contiki-os environment to find the location of 6 unknown nodes spread 3 m around the control node. The simulated results showed that the same result can be achieved if the same input data is used using the 3 algorithms regardless if they were implemented in the control plane or in the data plane. Furthermore, the experiment led to unnecessary energy consumption by sending information messages from the data plane to control plane to determine the localization in control plane.

5. Simulation result for some methods used in SDWSN

6. Conclusion

In this paper, we have presented the concept of SDN and highlighted its advantages that brings to traditional WSN management, the global overview of control plane allows to improved network performance during localization. Researchers are primarily interested in reducing energy and increasing the accuracy when calculating nodes location.

Researchers proposed several localization algorithms in SDWSNs and the simulation results showed that some algorithms succeeded in increasing the accuracy of the location calculation with less energy consumption.

Other localization techniques like Trilateration, Maximum likelihood estimation and the Linear Least Square Localization algorithm are fail to increase accuracy and moving the computational operations from data plane to control plane, it's just wasted energy and increase the load on SDN. However, this field need more work to exploit the centralization nature in SDWSN to increase accuracy of localization estimation and increase the lifetime.

CRediT authorship contribution statement

Baraa Abbas Shahal: Writing – original draft, Paper written, simulation. **Mohammed Najm Abdullah:** out put figures, related work, Writing – review & editing, english editing, references arrangement.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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