

Security in WSN as regards Node Life-Span

Final Research Report on Constrained Node Security



March 23, 2019

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Submitted to:

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CS-890DH: Topics on Communications

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# Abstract

# Introduction

Wireless sensor network (WSN) is a combination of small devices with capability of wireless communication, these smart devices are either called nodes or motes. Although WSN does not operate based of infrastructure, which is its main advantage because of flexibility of device deployment, there are lots of limitation or constrained associated with them and it includes low memory, moderate CPU power, lossy communication, narrowband media and power consumption. These limitations can affect the performance of a node in the network, which can then be a major drawback on the WSN. These constraints in the nodes can pose as possible security issues in the network, which can be a door for hackers to invade the network. (Hanes et al, 2017) Therefore, the project will be centered on researching into security measures, that can be implemented in WSN nodes to ensure proper data encryption without causing more limitations to the node such as Limited Memory, Power, Processing, Transmission spend and Communication.

# Literature Review

According to a conference paper written by Alsahli and Khan in 2014 about Security Challenges of Wireless Sensors Devices (MOTES), the paper is based on analyzing research papers on securing WSN and reliability of nodes/motes. They talked about how researchers have aimed their research only in the directions of security in WSN and totally ignoring the fact that optimization also plays a major role in WSN. This is because heavy computation, pose as a limitation which can possibly slow down node capability to function efficiently in its environment. Also considered in the paper, are some recommended solutions into how WSN can be safer in their environment (see Solution) and some security threats (see Problems). (Alsahli & Khan, 2014)

In a journal by Elhoseny et al in 2015, they proposed a method called "Dynamic Clustering of Heterogeneous WSNs using Genetic Algorithm (DCHGA)". The proposed method is for optimization of energy exhaustion using Genetic Algorithm. In the network, at every turn of message transmission, the dynamic structure of the network is decided. This creates an opportunity for heterogeneous factors like energy, the capacity of data processing, node as a cluster head and mobility of the node. their method was said to improve network life at 33.8% and for node mobility, it was between 12.6 and 9.8%.

In a conference article by Abdulasik and Suriyakrishnaan published in 2017, they came up with a system called multi-user multiple-input/output (MU-MIMO), where the purpose was to implement "multi-cluster heads" which will reside in every cluster to enable features like dual data uploading and to have the workload on the network balanced for energy efficiency.

In a journal paper by Li et al., in 2018, explored the challenges faced by software-defined WSNs (SDWSNs), which causes problems like traffic intensity on the network. An approach called Flow Splitting Optimization (FSO) algorithm to tackle and profile solutions to the problem of traffic load minimization (TLM) in SDWSNs. The solutions were to find best relay sensor node to carry communications split through, so not to cause problems like overloading a specific sensor path. (Li et al., 2018)

A dynamic key management approach was proposed by Kuchipudi, Qyser and Balaram in 2016. To ensure security for sensitive data being communicated within the network, a Mobile Agent Based Key Distribution (MAKD), is used to serve the purpose of key distribution and updating of shared keys. Generating and distributing key is accomplished by cluster head, for the purpose of energy conservation at sink node. The sink node sensor uses key sharing to establish trust with its neighbor sensor and forms a pairwise key for communication. The approach explored on the paper shows significant reduction in memory usage is accomplished by having the mobile agent store the public key. With key management, the aim is to ensure less storage, communication and most importantly computation and maximizing network lifetime as much as possible. (Kuchipudi, Qyser and Balaram in 2016)

In this article by Chen et al in 2017, they proposed and implemented a multi-sensor micro control unit (MCU) for wireless body sensor network (WBSN), which could be used by healthcare devices like Electrocardiogram (ECG) and other devices for healthcare monitoring. The network, works by first having the devices collect the data readings from the person, transform the data into digital data with an Analog-Digital Converter (ADC) device. Where the data is compressed, encrypted with Asymmetric Encryption etc. And then transmitted with UART interface. For the purpose of power consumption accountability, adaptive power controller and adaptive fuzzy controller are highly recommended for WBSNs. The MCU operates low-complexity which is essential for WBSNs, while also being "cost-efficient and high-performance architecture via the VLSI technique". (Chen et al in 2017)

# Project Description

The most important part in WSN has to do with security and maximizing nodes capability to function efficiently. Therefore, the focus of this project is to explore the type of security measures to be implemented in WSN, how the security will affect the performance of the node and finally should this security be placed at the Fog or Edge (Sensor) Layer.

The aim of the project is to research into various security methods in Wireless Sensor Network (WSN), where the life span of nodes/motes can be prolonged or extended to last long. The security measures, that can be implemented to ensure maximum security on nodes without causing a significant limitation on nodes such as Limited Memory, Power, Processing, Transmission spend and Communication.

Since we know that it is the coming together of various smart and small-sized device nodes mostly powered by battery, that makes up the entire building structure of WSN, then security in these nodes should be made of uttermost priority, this is because if any node is hacked or has viral it can possibly affect the entire WSN. This means security algorithms should be implemented that best suite the nodes, algorithms should not limit nodes capability to function with excess computation. Also considered, will be exploring into the level which security should be implemented. This brings us to Fog Computing, this is nothing but computing in the fog layer. Instead of having sensors communicate to the cloud, it talks to the fog layer which is one more close to the sensors. The work of Fog Layer is “analyzing IoT data close to where it is collected minimizes latency, offloads gigabytes of network traffic from the core network, and keeps sensitive data inside the local network.” (Hanes et al, 2017) If data encryption algorithms should be implemented in the Fog layer or at the Edge layer (directly in sensors). This is to ensure the full security of the data being transmitted at the Edge or Sensor level.

# Structure of WSN

Wireless Sensor Network is "a collaborative network of small wireless sensor devices, sensing a physical phenomenon" (Elshakankiri, 2018). Which also means that, it is a combination of smart/small devices with the capability of wireless communication, these smart devices are either referred to as Nodes or Motes. Because of how WSN operates an infrastructure-less architecture, it makes sensors nodes easy to deploy in various environments for the purpose of monitoring physical or environmental conditions, alongside data collection and communication via a communication medium to either Fog or Cloud base computing for future processing.

The below figure 1 depicts how sensors interacts with the environment they are placed in to collect various data types. The sensor deployed in environment has capability of wireless communication between each other. Interconnection between various sensor node allows better flow of traffic through nodes to base stations.

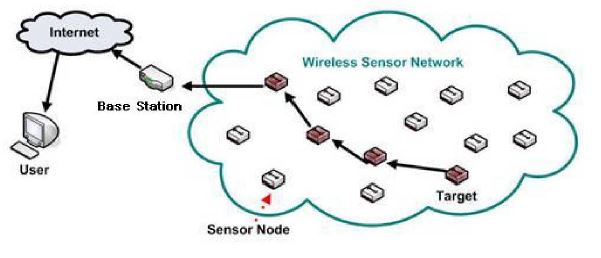


Figure 1: Typical structure of a WSN (Lu, 2013)

Figure 2 below, further illustrate the various components residing within WSN nodes. Where the nodes central feature is: Sensing Unit, Processing Unit, Communication Unit and Power Unit. Within each central node feature, there are also subcomponents which are responsible for carrying out some specific functionalities within its unit.

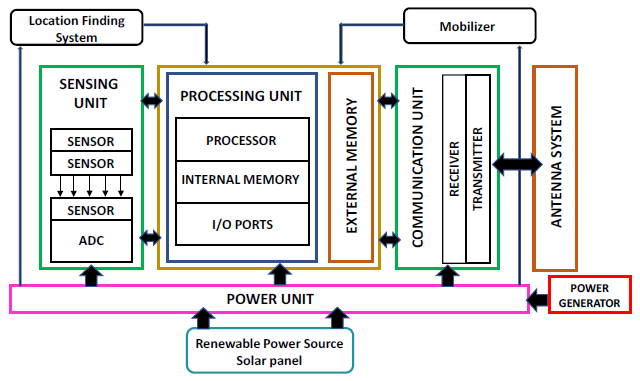


Figure 2: Components in WSNs (Akgül, Hasoğlu & Haznedar, 2018)

According to a book by Cisco on IoT Fundamental written by Hanes et al, in 2017. They described the above four central features as follows:

Sensing Unit: The unit comprises of Sensors and Actuators, where the responsibility of the Sensor is to sense or measure the environment they are placed in, while Actuators are responsible for acting on that environment, sometimes with instructions coming from the processing unit based on the data which was sensed by the sensor. Sometimes, the sensing unit only has sensing capability or multiple sensors without actuators. This is as a result of, the vast majority Sensor or Actuator node available for various tasks.

Processing Unit: This unit is responsible for coordinating all other parts on the node. which includes analyzing the data collected by the sensing unit, efficient energy distribution within the node and initializing instructions for data to be forward through the communication unit to another node. Because application use is different, there are varieties of processing units currently available. Also, some are widely used more than others such as Microcontroller (e.g. Arduino see figure 3). The use of microcontroller is mainly popular because of its small size, "flexibility, programming simplicity, ubiquity, low power consumption, and low cost."

Communication Unit: Being able to communicate efficiently has always been very crucial for WSN node. the communication unit is responsible for establishing communication with other nodes via the use of low-data-rate communication medium. For nodes to reach maximum distance, WSN nodes uses the communication medium to interconnect with other nodes and by doing this, traffic is passed through various nodes to reach the base station. Other reasons for interconnecting nodes are "cost, limited infrastructure availability, and ease of deployment." WSN node mainly use IEEE 802.15.4 standard, this is because it specifies variety of low-data-rate WPANs such as ZigBee and 6LoWPAN which is very much suitable for WSN node. Other communication means include 802.11 (Wi-Fi), 802.15.1 (Bluetooth), 802.15.4f (RFID), GSM/GPRS etc.

Power Unit: This unit provides energy for WSN nodes to function on the field without being connected to power supply. Because of the power unit, WSN nodes can be deployed in almost any environment. The power unit is a very crucial part of WSN nodes and efficient distribution of power for the node to function effectively is of uttermost importance for a reliable wireless sensor network.

## Topology in WSNs

The structure of WSNs is greatly impacted by the type of Network Topology being used. Where there are various topologies currently available such as Point-to-point, Bus, Star, Ring Tree and Mesh (Full/Partial) topology. There are few of the access technologies which stands out for connecting IoT devices and they include:

Peer-to-Peer Topology: This type of topology allows the direct communication of two devices, if they are within each other’s range of communication. it is said to be more complex and costly because the device is interconnected with each other.

Star Topology: A star topology is one which all the endpoints or deployed sensor devices are connected or communicate with a central point. The central point is also referred to as base station or controller (e.g. Hub, Switch, Access point etc.) is a device which is more powerful in terms of processing, communication range etc. Compared to the deployed sensor devices collecting the data. This implies that, all the information being collected by various deployed sensor devices, are passed to the central point maybe for future processing or even transmission to another base-station. Another variation of this type of topology is the Clustered Star Topology,

Where each star topology is implementing Full Function Device (FFD) capability, that can communicate and relay traffic bidirectionally with other FFD devices.

Mesh Topology: A mesh topology of the other hand, has two categories namely full and partial mesh. **Full mesh** operates life the peer-to-peer topology, where there is a direct connected between every other device, which sometimes result in connection redundancy. While on the other hand, **Partial mesh** is the type where not every device or node needs to be connected to every other node, but just few referred to as intermediate node or Full Function Device (FFD) with capability of interconnecting with one or more nodes, meaning a bidirectional communication can be established between two FFD devices or nodes. For a topology of this king, because FFD devices are interconnected, communication can span a wider distance range. Nodes without the capability to relay traffic of other are referred to as non-intermediate node or reduced-function device (RFD). Traffic is easily relied from one FFD to another until it gets to its destination or a base-station. (Hanes et al, 2017) (Groth & Skandier, 2005)

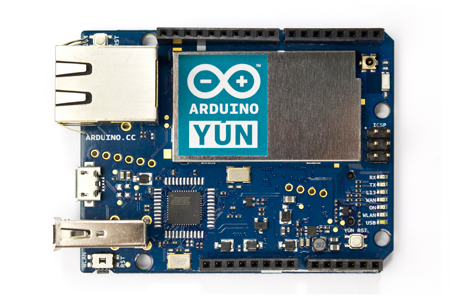
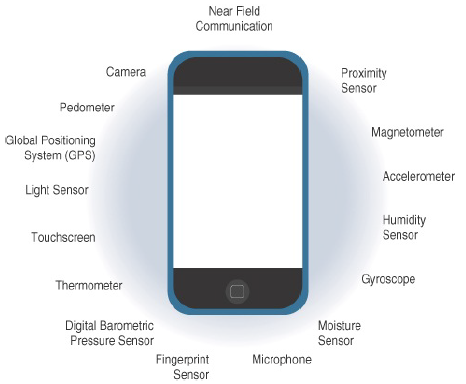
# Important components in WSN

# Sensor Nodes

Arduino Yun

NodeMCU

Smart Phones



Examples



Figure 5: ESP8266 Wi-Fi

Figure 4: Sensors on Mobile Phones phone

Figure 3: Arduino Yun

# Limitations of Nodes

Some of the existing limitations in WSN node are classed into the following: Sensing, Power, Processing and Communication. There are other treats like Environmental impact, Security etc. These are also potential limitations to the nodes.

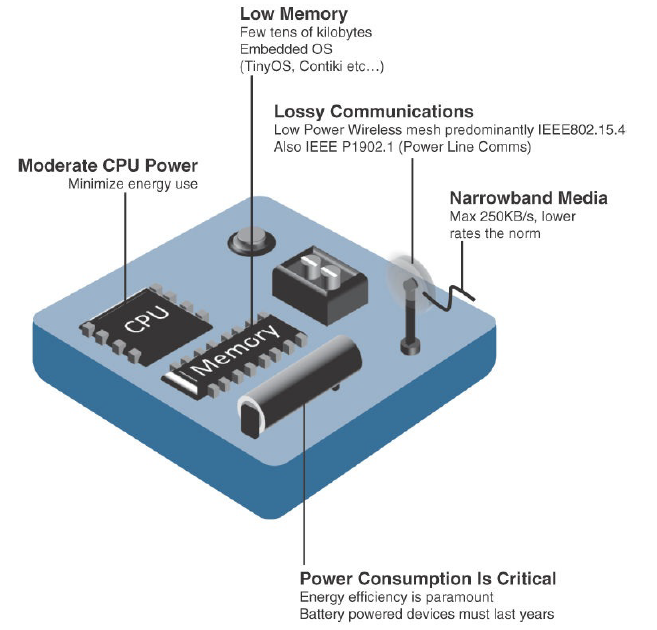


Figure 6: Design Constraints for Wireless Smart Objects (Hanes et al, 2017)

# Security and Algorithms

Cryptography referred to the art of securing data communication between a sender and receiver. When it comes to data transmission, security is of uttermost importance, as it ensures the data being transmitted is not being listened to by intruders like Eavesdropping. With cryptography comes the rise of encryption and decryption as security measures to ensure only the intended receiver can access the data being transmitted by the sender. **Encryption** is the process of converting plaintext into ciphertext, especially to prevent unauthorized access. **Decryption** is the reverse process, converting ciphertext back into the original plaintext. In a conference paper on Authentication Schemes for Wireless Sensor Networks by Tajeddine et al, in 2014. Explored in the paper are the three-key aspect in authentication as regards current cryptographic techniques available and they are Symmetric, Asymmetric and Hybrid cryptography.

Symmetric

This type of cryptographic algorithm that uses a single known key referred to as a secret key to both encrypt and decrypt data transmitted by sender/receiver. The encryption technique is popular because it is known to have less computation, processing, and very energy efficient. Which is the main reason why it is recommended for used in WSN constrained nodes. Example of symmetric algorithms are:

Data Encryption Standard (DES): This encryption uses a 56-bit key to encrypt a 64-bit block. Several series of steps are used to transform a 64-bit input into a 64-bit output. In order to reverse encryption, the same steps are repeated over again using the same key.

Advanced Encryption Standard (AES):

Rivest Cipher 4 (RC4):

Asymmetric

This encryption is popular for its additional security feature it implements. the technique is also referred to as Public-key cryptography, it uses two different keys. The first is called the Public key, which is used to verify a signature or encrypt the transmitted data, this key is made public. The second is called Private key, which is known only by the receiver or owner. For data to be transmitted from the sender, a receiver’s public key is used to encrypt the data being sent, the data can only be signed and decrypted with the private key known only by the receiver because they alone have the private key. Due to the large size of the key, asymmetric cryptography is known to consume processing power and uses more memory overhead compared to symmetric cryptography. Examples of algorithms are ECC, RSA, DSA, Diffie-Hellman key exchange etc.

Elliptic Curve Cryptography (ECC):

(RSA):

(DSA):

Hybrid

This technique combines symmetric and asymmetric cryptography together. it is like a middle ground for both techniques but tries to improve the downside of both methods e.g. an overhead problem in asymmetric technique. An example of Hybrid cryptography is Transport Layer Security (TLS) protocol, which is combining both asymmetric or public-key exchange e.g. Diffie-Hellman with symmetric-key for the purpose of data encapsulation e.g. AES. (Tajeddine et al, 2014)

In a conference article by Alkady, Habib and Rizk in 2013, they explored the two main WSNs issues with regards to security protocol. Their goal was to ensure significate reduction in both the overload in security protocols alongside message being encrypted and the key size. They then proposed a Hybrid Encryption Algorithm, which was a security protocol that basically utilizes the advantage of both symmetric and asymmetric cryptographic techniques. With the combination of both techniques, it will "provide high security with minimized key maintenance". The proposed protocol will further solidify security in terms of integrity, confidentiality and authentication. For encryption, the Elliptical Curve Cryptography (ECC) and Advanced Encryption Standard (AES) where both used, which was as a result of combining symmetric and asymmetric cryptographic. for Authentication was XOR-DUAL RSA algorithm and for Integrity was Message-digest (MDS). With all these together, their proposed hybrid encryption algorithms significantly outperform others with regards to computation time and the size of text being encrypted. (Alkady, Habib & Rizk, 2013)

In a paper by Randhawa and Dhami in 2018, a genetic algorithm was proposed to tackle and enhance the energy efficiencies in WSN network, it uses the concept of Virtual Grid-based Dynamic Routes Adjustment (VGDRA). Their approach was compared to LEACH and it was said to have better energy efficiency, this is mainly because of the dynamic and not static approach used. being able to balance the load on the network and optimizing the number of iterations resulting in a better result which are almost impossible using other techniques. the algorithm applies the "four principles of selection, evaluation, crossover and mutation." (Randhawa & Dhami, 2018)

# Fog Computing

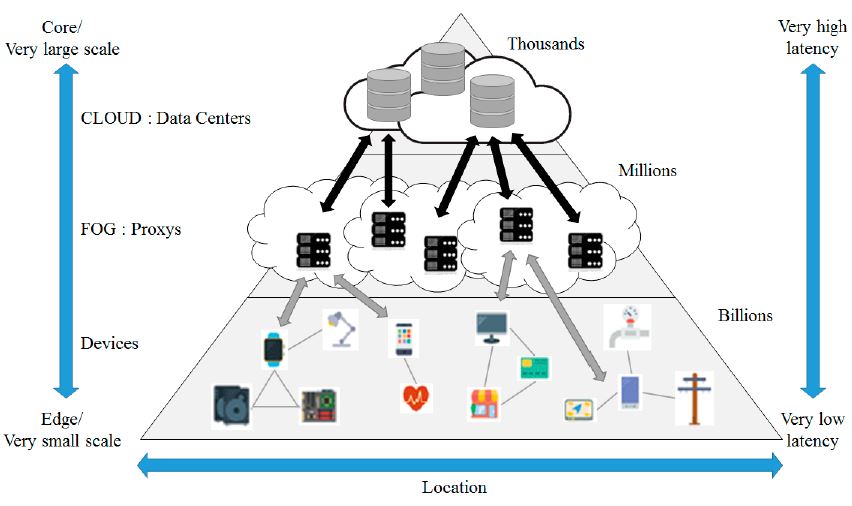
It was said that because of the needs and problems such as delayed service response time encountered, from Edge (sensor) nodes communication directly with Cloud Computing, there was a need to breach the gap between these two processes. Then came the introduction of Fog Layer "developed by Flavio Bonomi and Rodolfo Milito of Cisco Systems" and named by Rodolfo’s wife Ginny Nichols. The introduction of Fog Layer brought about Fog Computing which is the 3rd Level of the IoT Reference Model. As the number sensor nodes continuous to increase, so is the data generated by the nodes. "Fog computing is a model to manage data, conducting near field communication with a sensor." This was because data collected by sensor nodes at the Edge Layer, demanded real-time processing and information communication as close to the edge layer as possible. Fog devices has Computing, Storage and Network connectivity capabilities. (Hanes et al, 2017) (Cha, Yang, & Song, 2018)

Though fog computing is a part of the cloud as it originates from it, which means some or must of the security threats faced by cloud computing also applies to fog computing e.g. Data Altering, Unauthorized Access, Eavesdropping etc. It is more feasible to tackle the security threats in the fog computing, as more sophisticated security algorithms can easily be implemented in this layer than directly on the Edge. Security measures implemented on fog computing, allows services and application like low-latency network connections, amplifying Quality of Service (QoS) etc. This is because fog computing was designed to enhance efficiency and a significant reduction to the number of data being communicated to the cloud for the sow purpose of processing, fog computing gathers the data from the Edge or sensor level as it is closer than cloud, it has processing, storage, and networking capability meaning only important data are passed to cloud for processing and long storage. Fog computing serves as an intermediary layer between sensor nodes and cloud computing. (Alrawais et al, 2017)

For the paper by Zahra et al, published on IEEE in 2017, It was aimed at dealing with possible security issues/threats when data is being outsourced from fog client to fog node. They focused on using Shibboleth security protocol as medium of security authentication used on Cloud IoT network, it is known for being able to establish trust between its providers. "Shibboleth is one of the most widely used security protocol which focuses on authentication and user's privacy." They further proposed Shibboleth based Fog IoT network implementation, which is for the sole purpose of making sure only authorized communication can be initiated between Fog Client and Fog Node. (Zahra et al, 2017)

Diro, Chilamkurti and Nam in 2018 published a paper titled Analysis of Lightweight Encryption Scheme for Fog-to-Things Communication. In this paper, they proposed a novel encryption scheme for Fog-to-things communication. Some the main ideas discussed in the paper include security challenges, threats where they talked about how impersonation, injection and DoS are major attacks, security requirements such as confidentiality are very paramount, security architecture of fog node and possible fog-to-things communication solutions which is referring to implementing authentication like 802.1AR/ IEEE 802.1X and encryption like AES in fog-to-things communication.

## Structure of Fog Computing

Figure 7: Fog Computing (Cha, Yang, & Song, 2018)

# Possible Recommendation

As mentioned on the Project Description section above, a possible solution after reading all the above Literature involves deciding at what level security algorithms will be implemented. Direct implementation at the sensor layer could possibly result in limiting nodes capability to function efficiently. Therefore, so many researchers have suggested that security should be implemented at the Fog layer, for reasons being that the layer is close enough to the sensors level and have resources for large storage and processing capabilities. By doing this, the intense computational load is taken always from the sensors level.

# Conclusion

In summary, there are lots of research that have proposed various methods for tackling the major problems faced by the constrained node in WSN. Some of which, use cluster heads and base station communication to pass data, while other like fog computing implements security measures in fog, and have it overseen all the deployed nodes. The purpose of these is reducing overhead, processing power and storage in the sensor node. By exploring various literature above, now we have seen the different solution proposed by others and their implementation. Covered above, are some of the security that can be implemented for a constrained node in WSN. The final project will help to further understand why security measures should be implemented on the Fog layer rather than directly in sensor nodes.

# References

Abdulasik, A., & Suriyakrishnaan, K. (2017). Improvement of network lifetime with security and load balancing mobile data clustering for wireless sensor networks. In *2017 Third International Conference on Sensing, Signal Processing and Security (ICSSS)*. Chennai, India: IEEE. Retrieved from https://ieeexplore.ieee.org/document/8071641

Akgül, B., Hasoğlu, M., & Haznedar, B. (2018). Investigation and Implementation Ultra-Low Power PIC-Based Sensor Node Network with Renewable Energy Source and Decision-Making Unit. Wireless Sensor Network, 10(02), 41-58. doi: 10.4236/wsn.2018.102002

Alkady, Y., Habib, M., & Rizk, R. (2013). A new security protocol using hybrid cryptography algorithms. In *2013 9th International Computer Engineering Conference (ICENCO)*. Giza, Egypt: IEEE. Retrieved from https://ieeexplore.ieee.org/document/6736485

Alrawais, A., Alhothaily, A., Hu, C., Xing, X., & Cheng, X. (2017). An Attribute-Based Encryption Scheme to Secure Fog Communications. IEEE Access, 5, 9131-9138. doi: 10.1109/access.2017.2705076

Alsahli, A., & Khan, H. (2014). Security challenges of wireless sensors devices (MOTES). In 2014 World Congress on Computer Applications and Information Systems (WCCAIS) (pp. 1 - 9). Hammamet, Tunisia: IEEE. Retrieved from https://ieeexplore.ieee.org/document/6916650/authors#authors

Cha, H., Yang, H., & Song, Y. (2018). A Study on the Design of Fog Computing Architecture Using Sensor Networks. Sensors, 18(11), 3633. doi: 10.3390/s18113633

Chen, S., Tuan, M., Lee, H., & Lin, T. (2017). VLSI Implementation of a Cost-Efficient Micro Control Unit with an Asymmetric Encryption for Wireless Body Sensor Networks. *IEEE Access*, *5*, 4077-4086. doi: 10.1109/access.2017.2679123

Diro, A., Chilamkurti, N., & Nam, Y. (2018). Analysis of Lightweight Encryption Scheme for Fog-to-Things Communication. IEEE Access - Real-Time Edge Analytics for Big Data in Internet of Things, 6, 26820 - 26830. doi: 10.1109/access.2018.2822822

Elhoseny, M., Elleithy, K., Elminir, H., Yuan, X., & Riad, A. (2015). Dynamic Clustering of Heterogeneous Wireless Sensor Networks using a Genetic Algorithm, Towards Balancing Energy Exhaustion. *International Journal of Scientific & Engineering Research*, *6*(8), 1243 - 1252. Retrieved from https://www.researchgate.net/publication/281373886

Elshakankiri, M. (2018). Wireless Sensor Networks (WSN). Lecture, University of Regina.

Groth, D., & Skandier, T. (2005). Network+TM Study Guide: Exam N10-003, 4th Edition (4th ed., pp. 1 - 42). San Francisco: Neil Edde Sybex, Inc.

Hanes, D., Salgueiro, G., Grossetete, P., Barton, R., & Henry, J. (2017). IOT fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things (pp. 3 - 26). Indiana, USA: Cisco Press.

Kuchipudi, R., Qyser, A., & Balaram, V. (2016). An efficient hybrid dynamic key distribution in Wireless Sensor Networks with reduced memory overhead. In *2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT)*. Chennai, India: IEEE. Retrieved from https://ieeexplore.ieee.org/document/7755256

Li, G., Guo, S., Yang, Y., & Yang, Y. (2018). Traffic Load Minimization in Software Defined Wireless Sensor Networks. *IEEE Internet Of Things Journal*, *5*(3), 1370-1378. doi: 10.1109/jiot.2018.2797906

Lu, H. (2013). A Novel Routing Algorithm for Hierarchical Wireless Sensor Networks (M.Sc). University of Tsukuba.

Randhawa, N., & Dhami, M. (2018). Reduction of Energy Consumption in WSN using Hybrid VGDRA Approach. In *2018 59th International Scientific Conference on Information Technology and Management Science of Riga Technical University (ITMS)*. Riga, Latvia: IEEE. Retrieved from https://ieeexplore.ieee.org/document/8552974

Tajeddine, A., Kayssi, A., Chehab, A., & Elhajj, I. (2014). Authentication schemes for wireless sensor networks. In *MELECON 2014 - 2014 17th IEEE Mediterranean Electrotechnical Conference*. Beirut, Lebanon: IEEE. Retrieved from https://ieeexplore.ieee.org/document/6820562

Zahra, S., Alam, M., Javaid, Q., Wahid, A., Javaid, N., Malik, S., & Khan, M. (2017). Fog Computing Over IoT: A Secure Deployment and Formal Verification. IEEE Access, 5, 27132-27144. doi: 10.1109/access.2017.2766180