# A REVIEW OF ROUTING PROTOCOLS FOR CHILD TRACKING IN WIRELESS SENSOR NETWORK

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## ABSTRACT

*One of the widespread types of crime is child kidnapping where the number of cases is increasing each year. With the modern telecommunication technology, the child protection should be better now than before. This paper presents a preliminary study on routing protocol for child tracking using combined infrastructure of Wireless Sensor Network and Cellular Network. The real-time application in these networks would help the related parties to track the location of the missing child. From proactive point of view, the application would act as a preventive tool for child kidnapping. When the sensors in a Wireless Sensor Network detect child's presence, they have to transmit the data to an Access Point or the sink node in the network. Many routing protocols have been developed in the past, and all of them have their advantages and disadvantages. The outcome of this study is the selection of a routing protocol that is suitable for child tracking in Wireless Sensor Network.*

**Keywords**: Child tracking; child abduction; wireless sensor networks; preventive tool; routing; protocol.

## INTRODUCTION

One of the widespread types of crime that creates a lot of concern among Malaysian citizens is kidnapping, of children, to be more specific. Little children are constantly gone missing. Many kidnapping cases result in child raping and murdering. The number of cases keeps increasing each year. However, a lot of numbers of these cases go unsolved, which means that neither the criminals involved nor the child is found.

One of the latest cases of missing child is the case of a five-year-old Sharlinie. The little girl was last seen at the playground near her house on 9th January, 2008. It's been over a year now that she's missing, but, unfortunately, there are still no signs of the kid. It is very hard for parents to accept the death of the child, but it is much harder not to know what happened to the child, and where he / she is. Even after the 85 days, since the girl went missing, her father, Mohd Nashar Mat Hussain, believed she's still alive, on 3rd April, 2008 (Sagayam, 2008). Even though it's been a very long time, the hope for the good is always there. Parents suffer a lot, because until they get the result, they can't live their normal lives. But this doesn't only affect the parents. If the missing child has siblings, it's very hard for them, too. The minds of the parents are filled with something else, and they, usually don't take a good care of the other children.

The Malaysian government is encouraging parents to educate their children about the danger they face on the streets, but there is not much that a little child can do against a grown-up criminal. Children can be taught the basic things, such as, not to talk to strangers, or not to do what they ask them to do, but this will not guarantee their safety. The number of cases of missing children keeps increasing, but the number of the children found is not. The most regular places of the children being lost are the public places, like the malls, markets, and etc. where it's usually crowded. The authorities tried to solve this problem by installing the CCTV equipment at the places, but it seems to be not much effective.

**Problem Statement**

The problem of the cases of missing children is that, the children can't be traced to their location, where they are being taken or going by themselves. The missing child cases don't always involve kidnapping. Sometimes children get lost by themselves, going to the wrong direction and getting somewhere where there's nobody that can help them.

Increasing number of cases of missing children has made Malaysians more sensitive to this issue. Nationwide Urgent Response Information Network (NURIN) Alert has been set in place, waiting for the Cabinet's formal approval of its implementation in Malaysia. This system was proposed after the murder case of eight-year-old Nurin Jazlin Jazimin. This system is Malaysian implementation of America's Missing: Broadcasting Emergency Response (AMBER) Alert, implemented in the United States in 1996, and named after nine-year-old Amber Hagerman, abducted and murdered in Texas. AMBER Alert was used to trace the missing children through a comprehensive network of authorities and the community (The Star, 2008). These two systems are very useful to increase the chances of finding the missing child, when the whole community participates in the searching. But yet human capabilities are limited. NURIN and AMBER systems use the help of the community to search for the child. But the search is performed everywhere, because people don't know where to start looking. The child's last seen location is not of much help when abducted and taken to a new place. If the location of the child can be traced, soon after getting the report of the child missing, the police officials could take necessary measures to help the child. A better tracking system will help the police officials and other authorities to help to solve these cases.

**Proposed Solution**

Advances in wireless communications and technology in recent years have lead to the rapid development of sensor networks, where the sensors are low in cost and power consumption, and can perform multiple functions. Being small in size the sensors can still acquire and process data, and communicate to the other sensors, usually, through radio frequency channel. The sensors are easy to deploy and cost-effective, which have revolutionized the applications of remote monitoring (Wu, 2006).

Wireless sensor network (WSN) consists of small sensors. Each sensor can be referred to as sensor node in the network. These sensors are used to acquire the physical data, like, sound, light intensity, humidity, temperature from the environment where they are deployed (Mahgoub, 2006), (Wu, 2006). According to Haenggi M. (Mahgoub, 2006), the main features of sensor networks are that they have the self-organizing capabilities; they support short-range broadcast communication and multi-hop routing, have the ability to change the topology because of the failing nodes, have limited energy, memory, and computing and transmit power. These features are what make difference between WSN and other known wireless communication networks, such as other wireless ad hoc networks and mesh networks (Mahgoub, 2006), and single hop cellular networks (Wu, 2006).

Since the first introduction of Wireless Sensor Networks (WSN), growing research and commercial interest, that followed it, brought many applications of WSN. These applications were created for military, health, and civilian purposes (Callaway, 2004). One of the first developments of WSN applications, like many other developments, came in the military field. Application is developed for commanders to control their troops, weapons, supplies and etc. Magnetic and vibration sensors are used to detect the vehicle and people movements on the battle field. Sensors are used as intrusion detectors at the power plants, bridges, oil and gas pipelines. Some sensors can detect the biological attack, and give warning, thus, minimizing the damage. Medical area is another field where the research and development are the main priority. Medical applications of WSN include remotely monitoring of patients health status. The sensors may detect and store blood sugar readings, which is useful for people with diabetes, where the warning could also be sent to the physician of the patient. Athletes use wireless sensors to

measure the heartbeat rate, pulse rate and respiration rate. The civilian applications of WSN include Home Automation and Consumer Electronics used to comfort people. Wireless sensors, that detect the temperature inside the house, can activate the air conditioner or heater, depending on the current outside temperature. Lighting sensors can be used to regulate the indoor lighting, depending on the lighting outdoor, and the time of the day.

**Objectives**

The objectives of this paper are to do the preliminary study on the routing protocols, and choose the ones that will be suitable for the application of child tracking in WSN. The objectives are to be reached by reviewing the available routing protocols and checking whether it will be suitable for the use in the Child Tracking application.

The rest of the paper describes the following: Section 2 will discuss on the related works, routing protocols and their selection for the applications, describe several routing protocols and applications similar to the application of child tracking in WSN. Section 3 will discuss the methodology to reach the objective. Section 4 will show the results, and Section 5 will conclude the paper.

## RELATED WORKS

This section describes the routing protocols which might be suitable for the application of Child Tracking in Wireless Sensor Network, and the routing protocols used by the similar applications.

Applying Wireless Sensor Networks (WSN) to track children will help the authorities to reduce the searching area, and deliver the information to them in real time. But before the application can be developed, the research must be done on each component of the application. And each of the components has different issues to consider before the application can be developed. The issue discussed and addressed in this paper is the routing in WSN.

There are many routing protocols that have been discovered until now (Ács, 2007; Al-Karaki; Akkaya, 2005; Narasimha, 2006). Each protocol has its own considerations and network topology to be implemented in. There are several ways to separate the routing algorithms. K.Narasimha *et al.* (Narasimha, 2006) divided them into two: flat routing protocols and hierarchical-based routing protocols. Where flat routing protocols divide into several more among themselves, such as flooding-based, data-driven, query-driven, geographical and etc. Whereas, K.Akkaya *et al.* in their paper (Akkaya, 2005) divided the routing protocols into four, data-centric, hierarchical, location-based, and network flow and QoS-aware routing protocols. Ács *et al.* (Ács, 2007) divided the routing protocols into five categories based on their selection of the next hop of the message route. These categories are Content-based routing protocols, Probabilistic routing protocols, Location-based routing protocols, Hierarchical-based routing protocols, and Broadcast-based routing protocols. All researchers, (Ács, 2007; Akkaya, 2005; Narasimha, 2006), divide the routing protocols based on their routing attributes, and/or selection of the next hop algorithm. So, each protocol in a group are related to each other. Most of the protocols are derived and/or improved from the ones derived earlier.

To select a routing protocol for an application, it is necessary to understand and know the use of the application (Ács, 2007; Al-Karaki; Akkaya, 2005; Narasimha, 2006). Ács *et al.* (Ács, 2007) have proposed a taxonomy approach of routing protocols for wireless sensor networks in choosing the routing protocol to use in the application. In their paper they have identified that Network model, Operational model, and Routing objectives are important to determine the routing protocol to be implemented in application. Different applications require different network setup (Ács, 2007; Al-Karaki; Akkaya, 2005; Abbasi, 2007). The network model describes the characteristics of the base station and sensor nodes, which may influence the operation of the routing protocol in WSN. Most applications require the base station to be static, but some may need it to be dynamic or mobile. This is referred to as Network Dynamics or

Network Mobility. Another example of the importance of the network model can be the deployment of the sensors. The sensors can be deployed manually, at the locations defined in advance, or randomly, e.g. from the helicopter or airplane. If they are deployed randomly, which most of the routing protocols assume (Ács, 2007), the routing protocol self-organizes the network, so the nodes know their neighbors and the location of the base station(s), and if the nodes are deployed in pre-deterministic, manual, way, the data is routed over a pre-determined path. The operational model, which includes communication pattern, hierarchy, delivery method, computation, next hop and reporting model, defines the main orthogonal operation characteristics of the protocol. Data delivery model or reporting model, determines what initiates the data delivery process. The data delivery model is divided into three main protocols, time-driven (continuous), event-driven, and query-driven. And depending on the application two or more of these protocols can be combined into a hybrid model (Akkaya, 2005). Routing objectives include the expectations from the routing protocol, what the application requires the protocol to carry on. Ács *et al.* (Ács, 2007) divides the routing objectives into Non-real time delivery, Real time delivery, and Network lifetime.

Some applications may require the protocol to deliver the messages after some certain time interval; the others may require the protocol for the real-time operation and to increase the network lifetime. Therefore, some protocols address the issue of increasing the network lifetime by limiting the energy used for transmitting and receiving the messages. However, decreasing the energy used for receiving and transmitting may increase the message delivery latency. This may not be acceptable for the real-time applications (Ács, 2007). Among the routing protocols described by Ács *et al.* (Ács, 2007), only three satisfy the routing objectives of the Child Tracking application. Those are Threshold sensitive Energy Efficient routing protocol (TEEN), Adaptive Threshold sensitive Energy Efficient routing protocol (APTEEN), and SPEED.

TEEN was designed to sense the quick changes in the attributes that it is sensing (Akkaya, 2005). Usually it is used to sense the attributes like temperature, and when the temperature in the sensing area suddenly drops or rises, the sensor node will send the information to the sink. After forming the clusters, the cluster heads send the message, containing hard and soft threshold, to the other nodes in the cluster. These thresholds are the values to which the nodes react. Hard threshold is the minimum value of the attribute, sensing which will start the transmission between the node and the cluster head. Once the sensor's sensing goes beyond the hard threshold, it will send the transmission only when the value reaches the soft threshold. So, the soft threshold is used to limit the number of transmissions, reserving the energy. When sensing the changes, the nodes will send the data to their cluster head. Each cluster head will keep routing the same data to their respective cluster heads, until it reaches the base station, which is static.

APTEEN operates just like TEEN, except for some additions to it (Akkaya, 2005). Unlike TEEN, APTEEN also captures the periodic data. Like in TEEN, after the formation of clusters, in APTEEN, the base station sends the threshold values to the cluster heads. But unlike in TEEN, in APTEEN, the base station also sends the transmission schedule to the cluster heads. For this reason, APTEEN supports three types of queries, historical, one-time, and persistent. The historical queries can gather the past data, one-time query can capture the current state of the network, and persistent query will monitor the event for some specified period of time.
K.Akkaya *et al.* (Akkaya, 2005) state that both TEEN and APTEEN have the drawback of forming clusters complexity. But between the two TEEN is more energy efficient, because it limits the number of transmissions.

SPEED uses the geographic forwarding to find the paths of the nodes (Akkaya, 2005; He, 2003). SPEED uses five modules, Stateless geographic non-deterministic forwarding (SNFG) as a routing module, and other modules, beacon exchange, delay estimation, backpressure rerouting, and neighborhood feedback loop. Beacon exchange module is used to collect the location of the nodes and other information. When the node wants to transmits the data packet, it waits for the ACK message from the neighbors, then delay estimation module computes the estimated delay, and the node which meets the speed requirements is chosen for the

transmission of the data from the source to the sink, base station, which is in a fixed position. If none of the nodes meet that requirement, then neighborhood feedback loop module sends the relay ratio of the neighboring nodes to the SNFG, and if it's less than some randomly generated number between 0 and 1, then the packet will be dropped. And backpressure rerouting will be responsible for preventing the voids and send the message back to the source to find a new route.

A Sensor-Based Loosely Coupled Search and Rescue System Using Witnesses (CenWits) (Yick, 2008; Huang, 2005) is, as the name implies, a system designed and developed for the purpose of searching and rescuing the lost or injured hikers. The equipments required for the system are Access Point (AP) and Location Point (LP), which are static, GPS receiver and wireless mobile sensor, which are worn by the hikers. AP is used to collect the information from the hikers' wireless sensors; GPS receiver and LP are used to determine the location of the hiker. AP stations are located at the beginnings and ends of each route, and on the cross routes. When the hiker passes by any AP, the sensor worn by that hiker registers itself at the AP, and also dumps all of its memory contents. The memory contents of the sensor have also the information on the coordinates where the hiker met other hikers. This means that when a hiker passes by another hiker, their sensors automatically exchange data; the sensor stores the time and the location of the meeting. GPS receiver is used to determine that location. In the places where the GPS receiver doesn't work, LPs are deployed. Each LP knows its location. So, when two hikers' paths come across, but there's no GPS coverage, they will still register the time. And when after that the hikers pass by an LP, the location of the hikers' meeting point will be estimated by calculating the time passes since the meeting and the average hiking speed.

A project that has been developed for the same purpose of tracking children is "ionKids" (Eye on kids) (Huang, 2005; ionKids, 2009). The system allows the monitoring of up to four kids at the same time. The system consists of two main components, the Radio Frequency (RF) transmitter and the RF receiver. The RF transmitter is worn by the children on the wrists, and the RF receiver is held by the parent. The maximum range of the transmission is 300m. So, when the child goes out of that range, the signal will be received by RF receiver. RF receiver is also able to track to the point where the child went out of range.

H.-W. Tsai et al. (Tsai, 2007) have proposed the Dynamic Object Tracking protocol (DOT), which is used to track the objects that are moving, the target. When the target passes by the nodes in WSN, the nearest node will record its presence. As the target moves on, the more nodes will record the target when it passes by. The source then will re-track each node that recorded the passing of the target to reach to it. The source serves as a mobile base station. Even though source gets the list of nodes that the target has passed through, it doesn't have to go through all. DOT will update the route that the source has to go through to show the shortest path to the target.

## METHODOLOGY

This section describes the methods and the scope of the research where the study of the routing protocols fit it. The ways to determine the suitable routing protocol(s) for the application of Child Tracking in Wireless Sensor Network (WSN) will be described in this section.

### Research Scope

The scope of this research only lies within the WSN part of the application of Child Tracking in Wireless Sensor Network and Cellular Network (Figure 1).

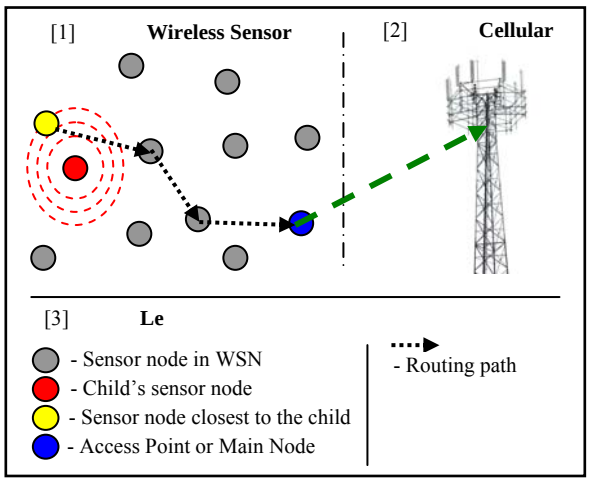

Figure 1. Research Scope.

Once the sensor in WSN detects the presence of the child being tracked, it will notify the main node in the network by sending a corresponding message to it. Illustrated in Figure 1, is the simple routing from the node that detected the child to the main node. This will change depending on the selection of the routing protocol, i.e. if the hierarchical-based routing protocol is chosen, the routing will be different.

**Research Methods**

To find the suitable routing protocol for the application it is necessary to identify the criterion, or criteria, based on which the protocols should be compared. As has been summarized in the previous chapter, some requirements of routing protocols are often conflicting. Therefore, the routing protocol with the most advantages for the application must be selected.

The applications of child monitoring, as well as other life related applications, are required to be real-time. Time is the main factor in this type of applications. Based on that, the main criterion for the selection of the routing protocol will be *time*. So, the main routing objective, described in the Section 2, will be the *Real-time Delivery*. The network lifetime is also important, because the system should be used for as long as possible. The network lifetime differs for each type of sensor, and its use. If the sensor transmits data very often, its battery will run out power, and the node will die. But with today's technology, the battery lifetime of the sensors keeps increasing. This will also increase the lifetime of the sensor. Therefore, network lifetime will not be the main factor in choosing the suitable routing protocol for the application. After *time*, the successful message delivery rate is also important. For a routing protocol that is to be used for the real-time application, delivering messages successfully is very important. Therefore, the lesser failures the protocol has in average, the better for the application.

The routing protocol taxonomy suggested by Ács *et al.* (Ács, 2007) can be used to select the routing protocols that can be used for the application of Child Tracking. Identifying the values for the network model, routing objectives and operational model is needed to make the preliminary selection. The first parameter to be selected is the routing objective. As has been mentioned it should be real-time. And since the routing of the data should occur only when the child's sensor is detected, the reporting model, which is under the Operational model, should be event-driven. Since the size and the cost of the network have not been determined, the network model will not be defined yet. The network model is mostly the hardware configuration of the network and will be determined later on.

## RESULTS AND DISCUSSION

This section will compare the routing protocols discussed in the related works section. The protocols selected are from the taxonomy suggested by Ács *et al.* (Ács, 2007), Threshold sensitive Energy Efficient routing protocol (TEEN), Adaptive Threshold sensitive Energy

Efficient routing protocol (APTEEN), and SPEED, and the routing techniques used in CenWits (Huang, 2005), ionKids(ionKids, 2009), and the Dynamic Object Tracking protocol (DOT) (Tsai, 2007).

Table 1 shows the comparison of the above mentioned routing protocols. Routing protocol similar to the one used in CenWits (Huang, 2005) would work with the application of Child Tracking, but it uses GPS as the main device to determine the location of the sensor. Although, GPS gives a very precise location of the object being tracked, it is also very costly. In the scenarios where CenWits don't use GPS, but use Location Points instead, the data of the location will only be sent when the sensor is near the Location Point. This is not acceptable for Child Tracking, because the purpose of the application is to know the location of the child all the time.

ionKids (ionKids, 2009) doesn't use Wireless Sensor Network. Therefore, its routing technique will not be considered for the application of Child Tracking in Wireless Sensor Network.

The other routing protocols are suitable for the application of the Child Tracking in WSN. SPEED routing protocol gives a good failure-free delay rate, and it is used for the real-time applications. SPEED also has uses a simple routing algorithm, which minimizes the transmission energy usage. TEEN creates clusters to minimize the number of hops, thus saving the energy and extending the lifetime of the WSN. Therefore, it will not be considered for the further comparisons. DOT was designed for the similar purpose as the application of Child Tracking in WSN. But in child tracking application, the base station doesn't have to be mobile.

So, TEEN, APTEEN, SPEED and DOT are the protocols that might suit the application of child tracking in WSN. But APTEEN is an extended version of TEEN. Although APTEEN might suit the application, the only difference with TEEN that it has, the periodic query of data, is not needed for the application of Child Tracking in WSN. Finally, the preliminary study of routing protocols, so far, has shown that TEEN, SPEED and DOT will be suitable for child tracking application.

Table 1. Comparison of Routing Protocols.

| **Protocol** | **Real-time** | **Using WSN** | **Base station (sink) mobility** | **Energy Aware** | **Hierarchical-based** | **Using GPS** |
|---|---|---|---|---|---|---|
| TEEN (Akkaya, 2005) | Yes | Yes | Static | Yes | Yes | No |
| APTEEN (Akkaya, 2005) | Yes | Yes | Static | Yes | Yes | No |
| SPEED (He, 2003) | Yes | Yes | Static | No | No | No |
| CenWits (Huang, 2005) | Yes | Yes | Static | No | No | Yes |
| ionKids (ionKids, 2009) | Yes | No | Mobile | No | No | No |
| DOT (Tsai, 2007) | Yes | Yes | Mobile | No | No | No |

## CONCLUSION AND FUTURE WORKS

The applications of Wireless Sensor Networks (WSN) are increasing, and the size of the sensor nodes getting smaller day-by-day. Using WSN for the purpose of tracking the location of a child will be very useful to the community. It could be used as a preventive tool for the rising crimes of child kidnapping. This paper has performed a preliminary study on the routing protocols, and has chosen three, Threshold sensitive Energy Efficient routing protocol (TEEN), SPEED, and Dynamic Object Tracking protocol (DOT), for further comparison to choose one to be used in the Child Tracking in WSN application. After this preliminary study, the selected protocols will be compared by simulation, and improved.

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