ISSN 1726-5479

SENSORS & TRANSDUCERS

3 vol. 14-2 Special /12

Physical and Chemical Sensors & Wireless Sensor Networks

International Frequency Sensor Association Publishing

IFSA

Sensors & Transducers

Volume 14-2, Special Issue
March 2012

www.sensorsportal.com

ISSN 1726-5479

Sensors & Transducers Journal (ISSN 1726-5479) is a peer review international journal published monthly online by International Frequency Sensor Association (IFSA). Available in electronic and on CD.

Sensors & Transducers Journal

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Volume 14-2
Special Issue
March 2012

www.sensorsportal.com

ISSN 1726-5479

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International Frequency Sensor Association (IFSA).

Sensors & Transducers Journal, Vol. 14-2, Special Issue, February 2012, pp. 228-241

Sensors & Transducers

ISSN 1726-5479

http://www.sensorsportal.com

Neighbourtables – A Cross-layer Solution for Wireless CiNet Network Analysis and Diagnostics

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Received: 15 November 2011 /Accepted: 20 December 2011 /Published: 12 March 2012

Abstract: For successful deployment of a wireless sensor network, reliable communication between the networks' nodes is crucial. When communication and other wireless sensor networks constraints are taken into account, networks can be analyzed efficiently. The diagnosis of the network's operation can be done using the information gathered by the sensor nodes in the network. This paper discusses wireless sensor network diagnostics, describes so-called neighbourtables used to collect diagnostic data of the wireless CiNet network and the construction of them using the synchronization and management messages. The neighbourtables are embedded to the CiNet network cross-layer architecture and this solution results to relatively small energy overhead consumption caused by them. The information stored in neighbourtables can be used to monitor network behavior and to improve networks' packet routing and fault recognizing for the nodes, in both, nodes' and centralized applications' point of view. *Copyright © 2012 IFSA.*

Keywords: Neighbourtables, Wireless sensor network, Diagnostic, Management.

1. Introduction

In recent years, study of wireless sensor networks (WSN) has become a rapidly developing research area. A WSN is a set of wireless sensor nodes where each node measures a physical value using selected sensor probes and sends the value to a database through specific sink nodes. Nowadays, WSNs are widely used in civil and industrial applications such as smart home or environment monitoring [1-3]. Compared to traditional sensing methods, wireless sensor networks technology offers some benefits: wide areas can be covered with inexpensive, energy-efficient battery-powered devices, which make long-term monitoring and real time access to measuring data possible. Often the nodes of WSN also are able to self-configure themselves, which enables quick and easy system deployment.

The use of WSN-applications also reveals many different constraints that can decrease the possible number of real application deployments. These constraints may be defined in different categories based on the constraints type, such as the system's memory, processors' limitations and energy consumption. Out-of-date communication equipment and their bandwidth as well as physical environmental and measurement factors related to sensors' location and calibration also may be the cause of different constraints.

A WSN can take into account some of the possible constraints by gathering diagnostic information from the network. For example, radio link quality is affected by many internal and external factors, and it can be evaluated by using the Received Signal Strength Indicator (RSSI). RSSI values as well as other diagnostic data, such as battery levels, the number of received packets etc., can be stored in one table, the so-called neighbourtable.

In CiNet WSN nodes, the diagnostic data is collected during the synchronization process to the node's neighbourtables that are embedded to be a part of the cross-layer architecture. The use of a cross-layer implementation reduces computational and memory requirements, since not all the information needs to be transmitted between application interfaces and protocol layers. The neighbourtables gives the nodes direct information about the network around them and also information about the sink node. The node can directly use the neighbourtable information to determine its routing and clustering possibilities based on the collected and calculated information about the neighbour nodes. Since the nodes' neighbourtables can be centrally collected to a server database, they can be utilized in different diagnostic applications. For example, we have developed a graphical real time application, CiNetView, to make wireless sensor network deployment and monitoring more reliable. The application visualizes, in real time, the nodes' relative locations as well as shows the links' quality, which make the deployment of WSN much quicker and easier.

This journal paper is an extended version of [4] and discusses reasons for wireless sensor network diagnostics and describes the so-called neighbourtables used in the wireless CiNet sensor network. The paper is organized as follows: First, we provide a brief description of some related research and discuss the useful diagnostic data and neighbourtables in WSN. Section 3 presents the neighbourtables construction in CiNet network as a part of the cross-layer entity as well as their usage. The construction is defined to be a part of the synchronization protocol. Other functionalities of the tables are also described in more detail. In Section 4 survey of the neighbourtables' energy cost is presented. Finally, some experiences of the use of neighbourtables in real wireless sensor network implementations are discussed and acknowledgements are given.

2. Network Management Issues

Analysis and monitoring of WSNs are highly evolving research topics in the field of wireless technology. However, real time performance of wireless communication is not that widely studied. In [5], Meier et al. discuss link behavior and metrics that can be used to evaluate link performance. They have used statistical link analysis in their studies. Ferrari et al. have done indoor performance studies of WSNs [6]. Sensor network diagnostics and visualization are discussed in [3]. However, there has not been much discussion on real time inspections of the changes in link qualities, whether uplink or downlink, in sensor networks or the architectures of the used diagnostic solutions.

For a customer's point of view, wireless network is fine when the wanted information is received and processed correctly, that is, when the network works properly. On the other hand, wireless networks include many different information pieces that can be used to give useful information about the networks' operational performance and reliability, not only for the user or customer, but also for the networks' maintenance crew as well. Sensor nodes' small dimension causes restrictions on its resources such as battery, memory, processing capability, used radio and communication standards etc. These consequently limit sensor nodes to perform large calculation tasks. Due to the limited amount of memory and space in the sensor nodes and the transmitted data frames, it is reasonable to define the relevant information and metrics that can be used in WSN diagnostics. Fynn [7] has done a collective study of WSN performance analysis methods and metrics, the topics including storage, routing, real time communication, power management and architecture. Jacuot et al. have discussed indirect diagnosis of the node state with few messages, using an SNMP-like LiveNCM management tool [8].

The main idea of WSN diagnosing and monitoring is to gather information about the relevant network parameters, which include: node states (battery level and transmitting power), network topology (the known neighbours of the nodes), link states (connection status of the nodes), and the topographical coverage of the WSN. A typical sensor network diagnostic and management system can perform different numbers of management control tasks based on the collected information about the network states. Some management tasks can include the remote controlling of the nodes, switching node on/off (power management), controlling the routing decisions (packet routing management), and performing network reconfiguration in order to recover from node and communication faults. In an ideal management case these operations are embedded to the system and they are performed automatically by the management software or some other management tool. There are some commercial network visualization and diagnostic applications, for example, MOTE-VIEW [9] and Surge View [10], developed by Crossbow Technology.

Wireless sensor nodes are typically not deployed in optimal conditions and therefore the configuration of nodes in WSNs may change dynamically. Thus, a sensor network management system should allow the network to be able to self-configure in the event of failures without prior knowledge of the network topology. Typically, most of the sensor network applications are designed in a way that they support network management, therefore no extra network management layer is needed.

In general the most important information from the node's point of view in every communicating network are its neighbours' addresses, since without them other information cannot be linked to a specific node and it is almost impossible to perform any data routing in through the network. Depending on the used systems and network solutions the node addresses can be defined differently, but the overall goal is to be able to identify each of the nodes unambiguously.

In a typical WSN the sink node is defined to be the so-called root of the network, and its relative location need also be known. Therefore, a metric called hop count is essential information for the nodes. The bigger the hop count the greater the number of relaying nodes that are needed for sending packets between the specific sensor node and the sink node. This value does not necessarily directly indicate the physical distance, but rather the relative length of a path that a data packet needs to be forwarded to reach the sink node. Additionally the hop count value tells the node the direction of the sink that the packet is to be sent to with the minimum number of forwarding retransmissions. Hop count values can also be defined to be calculated from the nearest gateway of the node.

Radio link quality is affected by many factors, which can be divided into a device's internal and external factors. The internal factors are caused by imperfections of the device's hardware or software. E.g., different radio chips do not behave exactly in the same way and each node has its own radiation pattern that is not uniform [2]. The external factors, such as fading, shadowing, multipath propagation, and dynamic environmental factors affect wireless communication and make it difficult to predict the radio performance beforehand. Link quality can be evaluated by using the Received Signal Strength Indicator (RSSI), which indicates the strength of the radio signal between two nodes at the receiver's position.

When sent packages are spread from the sink node to the last node in the network, it is possible that some of the packages arrive through multiple paths and are somewhat delayed. Nodes need to be able to recognize the packets that have been sent on the same synchronization period. Therefore, every packet has its own sequence number, which also needs to be stored. Some of the packets may be received from different neighbour nodes, meaning that the packets have traveled through different paths from sink to the receiver node. Packet routing is also one interesting network management related topic that will be discussed later. Routing using neighbourtables is studied in [11] and [12].

In a wireless sensor network nodes naturally need energy to operate, and they usually are battery powered. The lifetime of a sensor node is mainly determined by the power supply since battery replacement is not typically an option in sensor networks, especially in environmental monitoring cases. The varying shape and utilization of the network cause that the battery levels of the nodes do not consume at the same rate all over the network. The longer the lifetime of a sensor, the more stable the WSN. Therefore, it is essential to know that how much the batteries have power left.

In addition to these considerations, the nodes can be programmed to have several different counters that can be set to count, for example, the number of received and missed packets. These counters can then be used to calculate, e.g., throughput and reliability values of the sensor or relay nodes. All the introduced information can be used on its own or together as a combination to enhance different management and diagnostic operations in the network deployment and monitoring phases, such as topology control and packet routing. But before these information pieces can be utilized, all the information needs to be stored somewhere. One solution is to use neighbourtables that are embedded in the management entity of the used cross-layer architecture. The solution allows all the protocol layers to utilize same information, which reduces space needed.

Typically, when talking about neighbourtables, the topic equates to a conventional routing tables. A short comparison of neighbourtables and routing tables is needed. A routing table is a set of rules that is used to decide where data packets traveling over network will be directed. Each packet contains information about its origin and destination. The routing table contains the information necessary to forward a packet along the best path toward its destination. Usually a routing table includes the following information:

- Destination: The address of the packet's final destination;
- Next hop: The address to which the packet is to be forwarded;
- Metric: Assigns a cost to each available route so that the most cost-effective path can be chosen.

Our definition of neighbourtable is that neighbourtables basically include, not only the same information as routing tables, but also some additional information. They can be used to aid routing decisions, but they can also be used in different diagnostic and management solutions as well. For a single node's point of view, a neighbourtable is a multifunctional set of information about the nodes' neighbour nodes and the links between them. Globally speaking, the neighbourtable file, constructed by the server, includes all essential information about the whole network, and the whole network's operation can be diagnosed and monitored in real time from there. One approach that uses additional messages to construct and utilize neighbourtables is considered in [13].

3. The CiNet Neighbourtable

We are using CiNet nodes [2, 14] in our study. CiNet is a research and development platform for the WSN implemented in Kokkola University Consortium Chydenius. The CiNet platform is specially designed for WSNs and consists of inexpensive, standard off-the-shelf components. There exist two different versions of the platform. Each version uses different IEEE802.15.4 radio modules, but the system architecture is common. All 2.4 GHz versions can work seamlessly in the same network. The CiNet node includes all the basic components necessary for WSNs. The CiNet nodes are also ported to Jennic radio module [15] and ZigBit module with ATmega1281/AT86RF212 radios [16]. Neighbourtable usage is also implemented to these modules and the research work is ongoing. The system architecture of a typical wireless sensor network application using the CiNet network is displayed in Fig. 1. In our CiNet network, the nodes use cross-layer architecture [14].

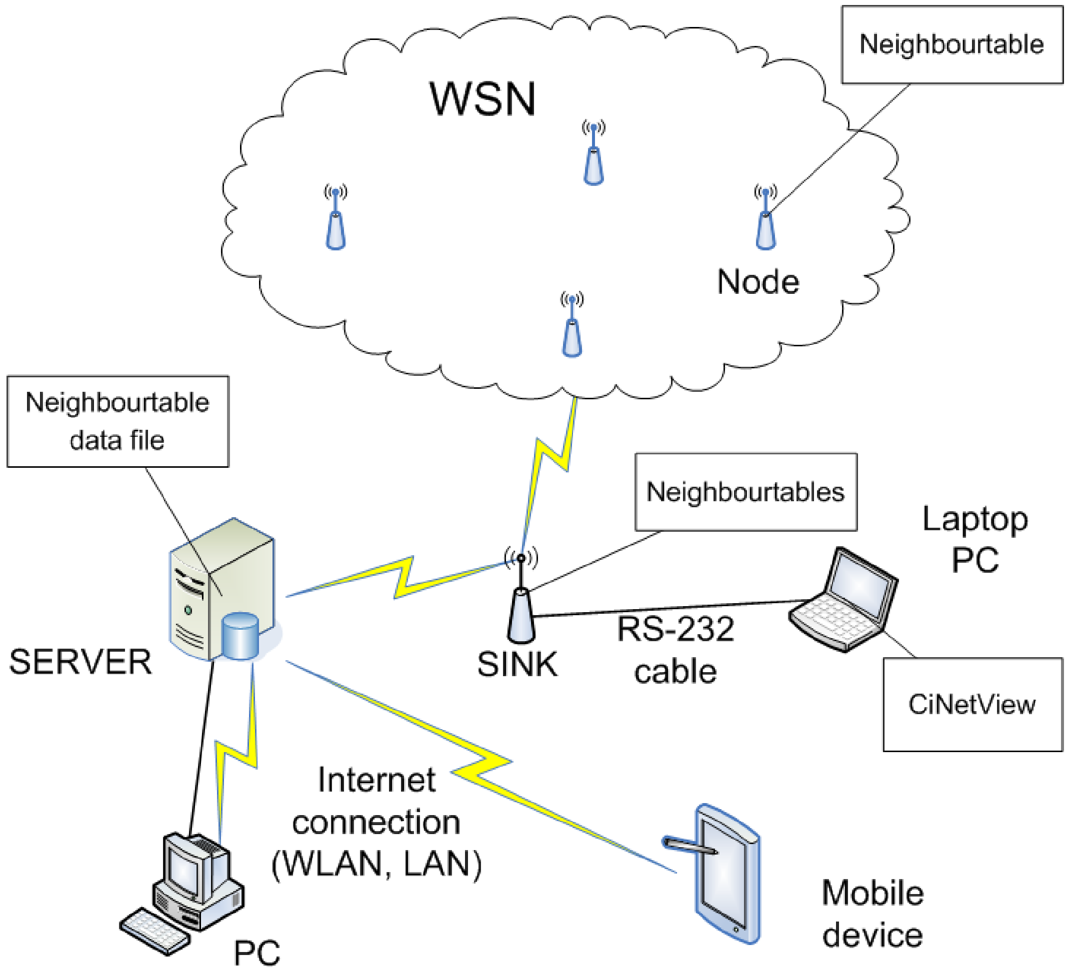

Fig. 1. The system structure of CiNet network.

The main idea of the cross-layer architecture is to implement a wireless sensor network's basic tasks, such as topology management and power saving functionalities, as separate protocols in a cross-layer management entity. Data structures, which are in common use, are in this study implemented in the cross-layer management entity as a neighbourtable data addition. The use of a cross-layer implementation reduces computational and memory requirements - not all the information needs to be transmitted between application interfaces and protocol layers. The architecture also allows the implementation of the application and protocol stacks be as simple as possible, since they are practically free of the tasks related to network management.

In every node, the neighbourtable is stored to one common data storage in the cross-layer management entity, where all the protocol stack layers can utilize the same information, see Fig. 2. This reduces the total amount of memory storage space needed, but the use of cross-layer architecture causes challenges related to maintenance, which have to be considered in the implementation. The problem has been approached by using message multiplexing in the data link layer and modular structure in the cross-layer management entity.

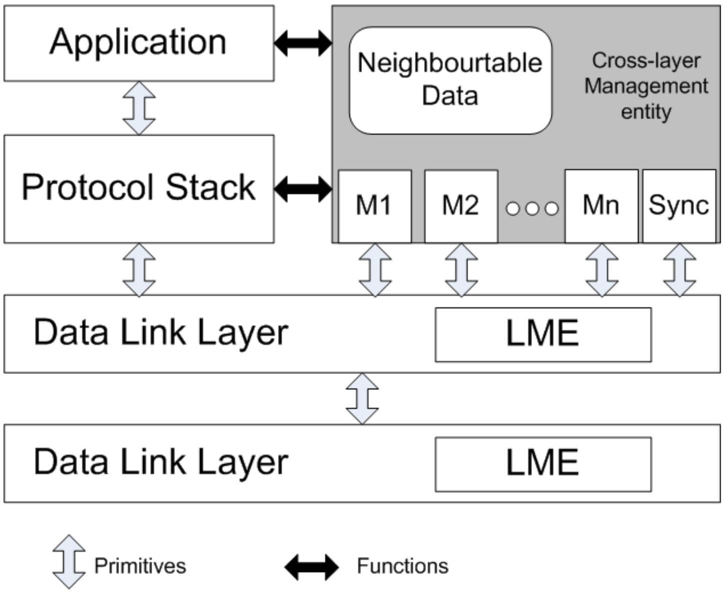

Fig. 2. CiNet network's cross-layer architecture.

Basically the neighbourtable of each node consists of *d* levels with *b* entries at each level. More precisely, every level *d* is a different neighbour of the node and each entry *b* includes stored information, such as node ID, battery level, RSSI and hop count.

All the nodes' neighbourtables are also collected to a single data file on a server, from where all the information can be retrieved. This centralized neighbourtable can be used in different WSN management and diagnostic applications and tools. The format of the file is shown in Table 1.

Table 1. Format of the server's neighbourtable data file.

Seq No	Node ID 1	Neighbour 1 data	Neighbour 2 data	…
Seq No	Node ID 2	Neighbour 1 data	Neighbour 2 data	…
⋮	⋮	⋮	⋮	⋮
Seq No	Node ID N	Neighbour 1 data	Neighbour 2 data	…

3.1. Neighbourtable Construction

In a CiNet network, each node constructs and maintains its own neighbourtable, as defined in Table 2, in which the node stores information about its neighbours, which are the nodes that it hears. The neighbourtable of each node is updated in every synchronization period of the network, see Fig. 3. The neighbourtable construction and update is defined to be one part of the synchronization protocol. The sink node broadcasts the synchronization message isotropically, and every node that hears it broadcasts that message onwards through the network during a predefined time period. In this way the whole network can be synchronized. The synchronization frame structure is shown in Fig. 4(a). The SYNC frame also includes additional data that is not used in the neighbourtables, such as the CMD and a command byte that can be used to control the nodes' operation. Before relaying the synchronization message, the nodes update it with their own information. Based on the received synchronization messages and the data included in the synchronization frames, the nodes update their neighbourtables. Note that the synchronization messages are heard by all the nodes' neighbours, including the predecessors, which means that the neighbourtable information can be collected in both directions. To prevent any ping-pong effect, the nodes broadcast the synchronization message only once in every synchronization period. Continuous synchronization of the network is vital to ensure valid operation of the network.

Table 2. CiNet nodes' neighbourtable.

U16INT u16NbAddr	Neighbor address
S8INT s8RSSI	Neighbor link RSSI value
U8INT u4Bat:4	Battery level of the neighbor
U8INT u4HopCnt:4	Hop count of the neighbour
U8INT u8NodeType	Sink, Relay, Sensor
U16INT u16Received	Number of received sync packets
U16INT u16Missed	Number of missed sync packets
S8INT s8AvgRSSI	Average RSSI of the neighbour link
S8INT s8PathRSSI	Path RSSI (path's weakest RSSI)
U8INT u8PrevSeq	Previous sequence number
U8INT u8Ntp	UpLink throughput
U8INT u8UplinkTp	Path throughput
U32INT u32NbLastSeen	Last seen time, for entry maintain
U8INT u8Status	Sync status

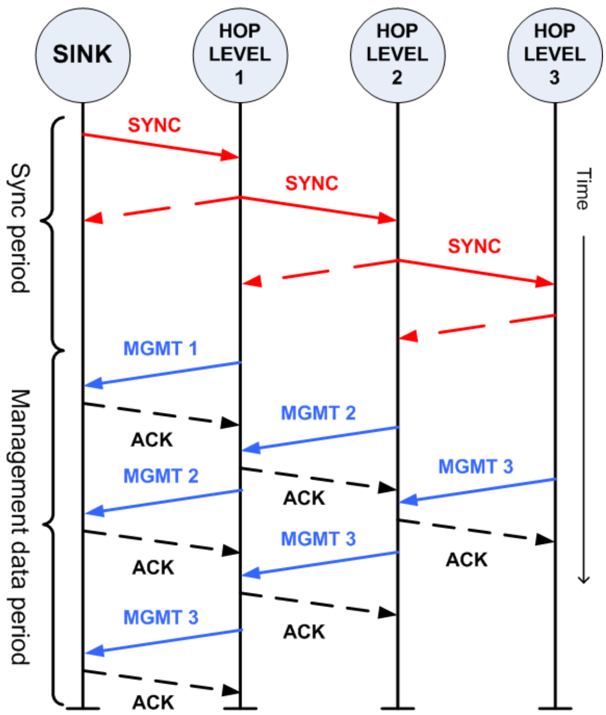

Fig. 3. Synchronization, management and ACK messages during one synchronization period.

After every synchronization period, every node in the network now has real time information about the network around, including information about the sink node. After the synchronization period, the nodes also can send the neighbourtable information through the sink node to the server during the management period. The time interval of this neighbourtable update can be defined to meet the application demands. Typical update interval is one synchronization period, but it can also be much longer.

The management frame includes a section where the neighbourtable information is sent. The management frame structure is shown in Fig. 4(b) Diagnostic and other management data is sent (and acknowledged) as a unicast transmission through a selected route to the sink node. If retransmissions are not needed, each management frame is sent once in every management period.

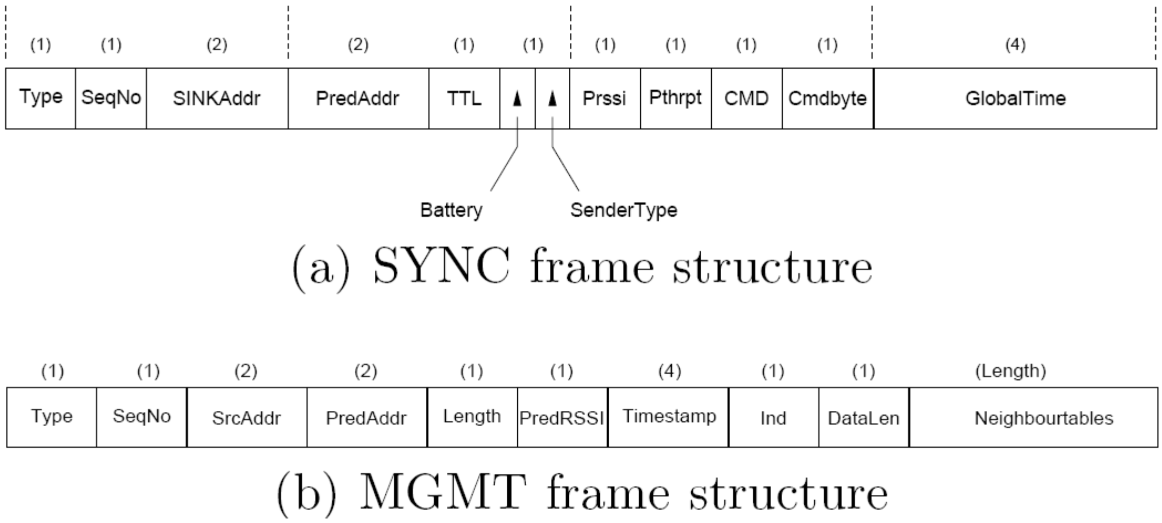

Fig. 4. Synchronization and management frame structure.

3.2. Neighbourtable Utilization in CiNet Network

Neighbourtables are specially used for collecting information for real time deployment and for monitoring of the WSN. They can be locally used in the nodes or with some management tool. Since every neighbourtable of every node is known, it is possible to count and utilize different diagnostic values about the whole network using the information collected to the neighbourtables.

One of the most useful values that can be calculated from the neighbourtable information is the throughput of one link. The throughput value can directly indicate the reliability and robustness of the sensor node or a link between two nodes. A good throughput values should be near 100 %, but in WSNs typically at least some of the packets are missed. Since network synchronization is done periodically, the node knows how many times it should have heard the synch message after having received the first synch message. The sequence number of the received message is checked, and if the number has increased more than one, then a packet or packets has been missed. The throughput information is calculated based on the nodes' packet counter values and then updated to the nodes' neighbourtable.

When a node has been working for a while, the throughput value will settle to some level that will indicate the basic information about the links reliability. If the throughput value suddenly degreases, it will be a clear indication about something having changed or broken in the network, for example, a car might have been parked between two nodes, interfering with the signal.

RSSI values can be used to determine whether the link is acceptable or not. The nodes typically have been programmed to respond to a predefined RSSI lower bound to determine whether the link is strong enough to be useful. In WSNs, radios typically operate in the 2.4 GHz ISM band and are based on the IEEE 802.15.4 standard due to which RSSI value -85 dBm is considered to be the acceptable lower bound and according to [17] RSSI value -75 dBm or greater indicates over 90 % packet reception rate (PRR) over single link. It is also possible that the link quality may only be suffering from temporary deterioration, for example when objects, such as people and cars, suddenly cross between the nodes. Therefore the neighbour RSSI values also need to be averaged to avoid useless routing changes. Since the data packets' path RSSI value, from node to sink or vice versa, cannot be any larger than the worst link's case, the path RSSI values indicate the lowest RSSI value between the sink and the node. This information can directly be used in packet sending and routing decisions. Meier et al. [5] have used RSSI values too, but also, e.g., number of packets, average packet reception rate and link quality indicator (LQI) to perform efficient WSN link diagnostic.

A node's battery level information can be used to alert the network supervisor to do network maintenance. If a low battery level is noticed before a link stops working, due to power out, it is possible to keep the network topology controlled. Another point is that if the node's battery level is decreasing more rapidly than in the other nodes, it is possible that that the node is not working correctly, or that it is relaying too much data. The battery levels of the nodes' neighbours can also be used to define the data routing. If the battery level of one node is getting low, then an alternatively routing is used, if possible, to avoid unnecessary dropouts.

For packet routing, nodes typically use basic routing tables. Using the routing table, nodes can efficiently transfer data from each node to a sink, but the routing decisions can be thoroughly justified with the extended information of the neighbourtables. In some solution the routing tables can be simplified just to be a list of addresses whose order can be predefined according to the cost metric information in the neighbourtables. Naturally, the nodes' address information is the most important, but other information can be used to optimize the networks' routing performance and reliability. Almost all the information that the neighbourtable contains can be used to improve the network's data routing. In most cases node addresses and some cost metric are used together to create the most energy efficient route for the transmitted data packets.

In our solution, the routing protocol can use hop count and RSSI values to help the decision of the optimal packet transmission direction and route. The minimum hop metric is used in many routing protocols due to its simplicity and isotonicity [18]. Hop count value can directly indicate the logically shortest transmission path from a node to a sink. RSSI values also indicate the links' or the whole paths' quality. In order to maximize packet throughput, it is reasonable to choose links that are more likely by the next relay. Throughput values indicate the total amount of packets that have successfully been transmitted through a specific link. If a link has a good throughput value, it is more likely to perform the transmission successfully again.

Transmitting power for the nodes' radios can also be optimized using the RSSI information in the neighbourtables. In some applications and hardware solutions, it is possible to adjust the radio chips' transmitting power in real time. An acceptable lower bound of RSSI can be fixed, and, based on it, the transmitting powers can be lowered or increased when necessary.

4. The Cost of Neighbourtables

In CiNet network, the nodes are synchronized periodically to ensure valid operation. The length of the synchronization period, during which the neighbourtables are collected, depends on the application used and on the WSN measurement solution. Thus, data collection is embedded to the synchronization messages, and no extra messages are needed to be sent to collect the neighbourtable information. The maximum size of the SYNC frame is 16 bytes. Of these, 4 bytes are directly related to the neighbourtable usage. It can be stated that basically almost all information in the SYNC frame would be sent even without the neighbourtable usage, since the information is used for routing protocols in any case. Therefore, it can be said that the neighbourtables are filled with almost free of additional energy cost. Only the size of the synchronization frame is increased. Based on the standard the it takes 32 µs to transmit a one byte. The cost of the neighbourtable construction is caused from these 4 extra bytes for every transmitted SYNC frame. The energy cost of the neighbourtable construction in one node during one broadcasted SYNC frame is 13.8 µJ. The energy cost of the SYNC frame is calculated similarly as defined later for the management frames energy cost. The SYNC frame is broadcasted and therefore the construction cost of the whole networks depends on the number of the nodes.

The memory space is limited in the sensor nodes. As every node can store the information of eight neighbours and as 18 bytes of memory have been reserved for each neighbour, this means a maximum memory use of 144 bytes (8 x 18 bytes). From these, the six best are sent in the management phase (one management frame can fit six neighbours).

The main additional cost of the neighbourtables incurs when the tables are also sent to the sink node as a part of the management frame. This increases the number of sent packets and time to spend for sending the data. It also consumes more energy. The total cost of one sent and received management frame is defined as

$$E_{frame} = \Delta E_{tx} + \Delta E_{rx} \tag{1}$$

$$\Delta E_{tx} = P_{tx} * t * U_{bat} \tag{2}$$

$$\Delta E_{rx} = P_{rx} * t * U_{bat}\,, \tag{3}$$

where $\Delta \boldsymbol{E}_{tx}$ and $\Delta \boldsymbol{E}_{rx}$ are the transmitting and receiving energy consumptions respectively. Communication time between nodes to transmit and receive one neighbourtable is t, the used battery voltage is U_{bat}. P_{tx} and P_{rx} are the transmitting and receiving energy consumptions. The CiNet nodes' numerical characteristic values with Atmega128L+TI CC2420 2.4 GHz transceiver for energy consumption based to our own measurements and datasheet information are shown in Table 3.

Table 3. CiNet nodes' power consumption with Atmega128L+TI CC2420 2.4 GHz transceiver.

P_{tx}	Transmission power consumption	30 mA
P_{rx}	Receiving power consumption	19.7 mA
t	Communication time for one full (6 x 18 bytes) neighbourtable	2 ms
U_{bat}	Used battery voltage	3.6 V

The energy overhead cost of transmitting and receiving one management frame, with full neighbourtable information (6 x 18 bytes) is illustrated in Fig. 5. When only the energy cost from the radio transmission and receiving are taken into account and excluding all the energy losses caused by the measurement sensors and devices, our measurements and calculations have shown that a management frame transmission takes about 0.216 mJ of energy and receiving takes about 0.142 mJ, so the total consumption is about 0.4 mJ [2, 19, 20].

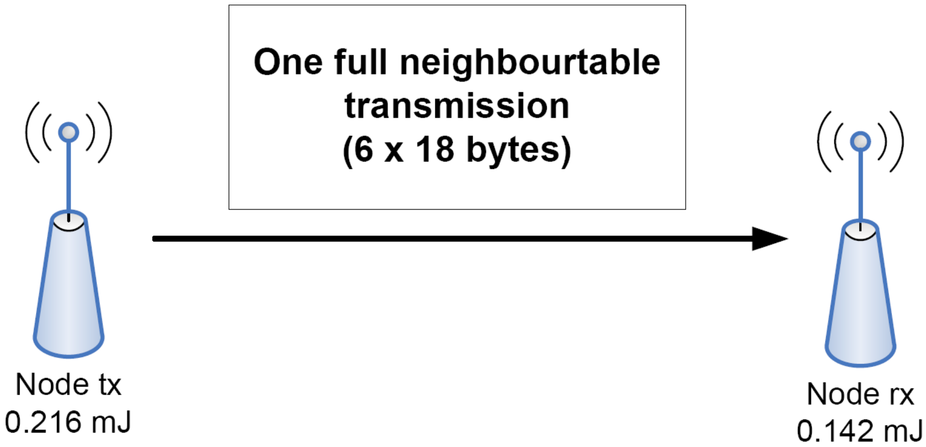

Fig. 5. Energy costs of transmitting and receiving one full neighbourtable.

The energy overhead of the whole network to transmit the neighbourtables to the sink node depends on many different factors. These include, for example, the size of the network used, the number of hops and the application that determines the number of sent and relayed packets. The transmission time of one node is determined by the size of the sent packet. The node's transmission power and battery voltage also affect energy consumption. The size of one transmitted management frame that includes the neighbourtables is between 50 and 128 bytes, depending on the number of the node's neighbours.

5. CiNetView: a Neighbourtable Utilization Tool

Neighbourtables can be used to help sensor network diagnostic and visualization. We have been using neighbourtables in our CiNetView application [21]. The CiNetView application is a graphical tool for making the deployment and monitoring of a WSN easier and more assured. CiNetView is based on diagnostic information that the nodes have collected and stored to neighbourtables. The application is server-centralized and it reads information from the neighbourtable file. CiNetView can be used in both indoor and outdoor deployment cases. If the physical location of the sensor nodes are not exactly known, then the application displays network topology based on relative locations produced by the MDS-algorithm, example is shown in Fig. 6. The MDS-algorithm can also be used to define approximated locations for the sensor nodes, based on the RSSI values, by using different signal propagation models. If it is possible to get an aerial photo, cartogram, map or perhaps a blueprint from the network deployment area, it can then be given as a background image to the application, where the user can exactly pinpoint the nodes' true locations, example is shown in Fig. 7.

The user can select different variables, such as RSSI and throughput of the nodes that are displayed individually over the link lines by the application. Based on the selection CiNetView displays the essential network diagnostic information and helps the user to see the changes in the network's behaviour. The different network variables are read straight from the neighbourtable data file. Because of the real time presentation of the network's connections and the quality of these connections, the advantages of this application can be seen most clearly in the network's deployment phase. The application can be used to diagnose and monitor a WSN through the network's lifetime.

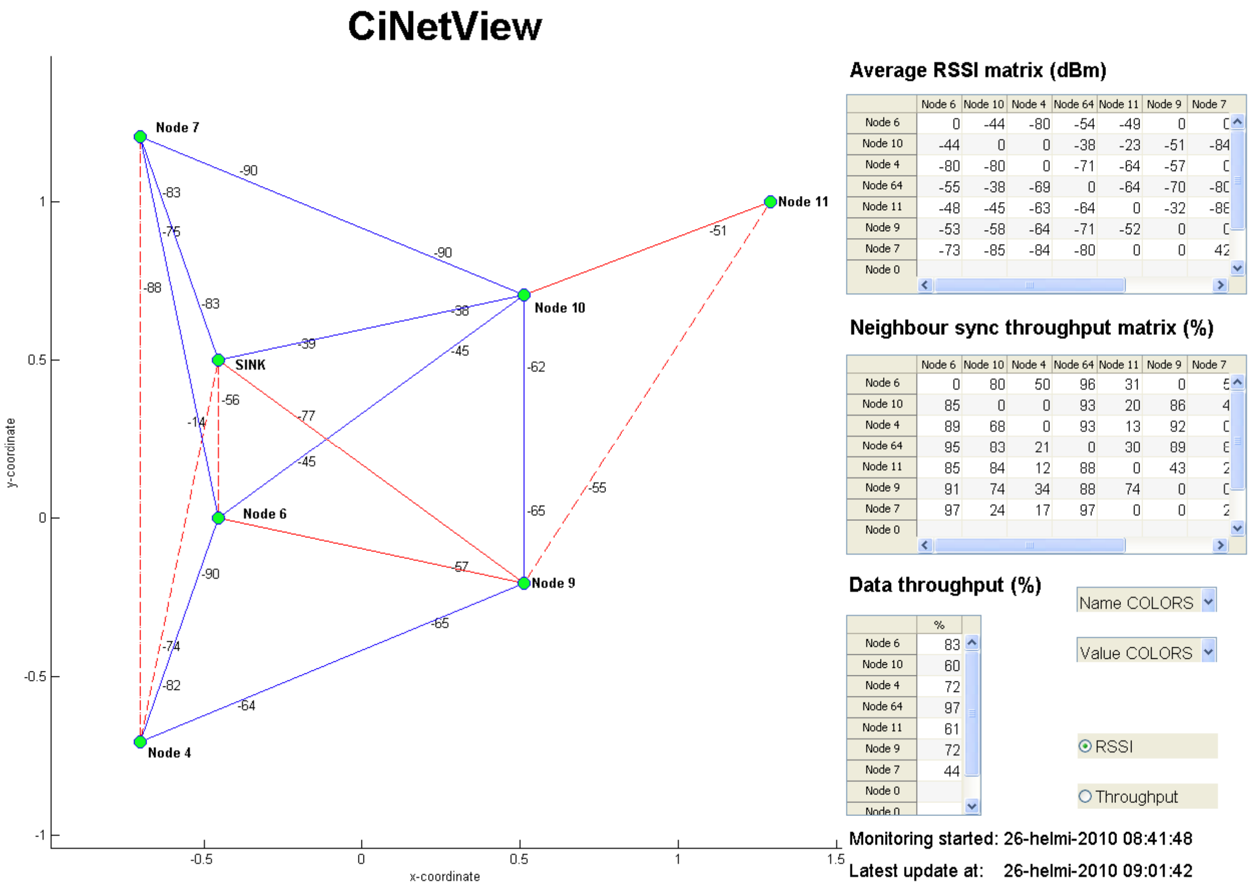

Fig. 6. CiNetView's MDS-algorithm based topology presentation.

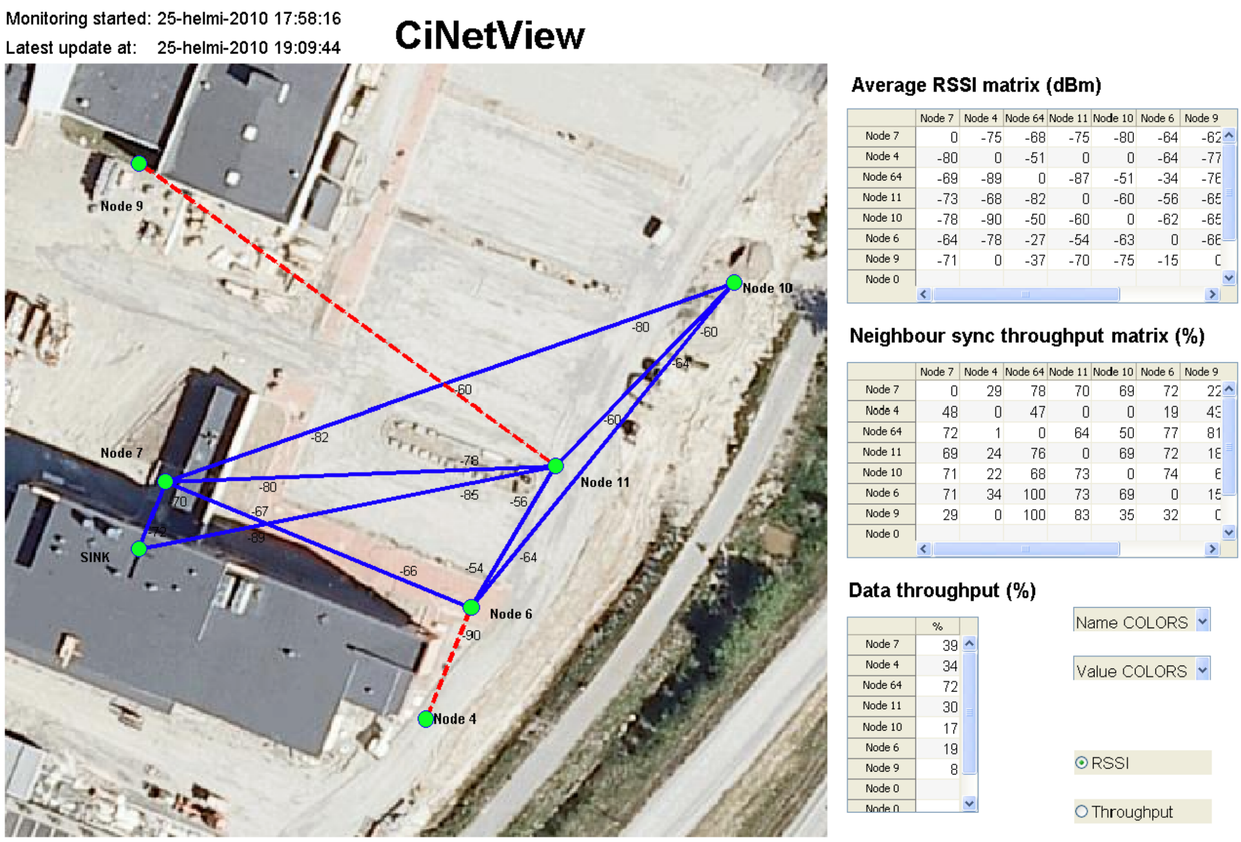

Fig. 7. Parking area of University Consortium Chydenius in Kokkola.

6. Conclusions

In this paper, we have discussed the main topics about wireless sensor network diagnostics and defined the essential metrics for WSN diagnostics. We have presented how the CiNet neighbourtables are constructed, without significant additional transmission overhead, using modified network synchronization messages. In every node they are stored to common data storage in the cross-layer management entity, where all the protocol stack layers can utilize the same information. The cost of the neighbourtables stays relatively small. The neighbourtables can be used locally by the networks' nodes or server centralized in WSN diagnostic and management, for example by using CiNetView application, which is specially designed for WSN visualization and monitoring. The information stored to neighbourtables can also be used in routing protocols to define the best packet routing selection.

For future work the idea is to improve the utilization of the neighbourtables from the nodes' point of view and in general diagnostic applications. The goal is to make a database that collects historical data from the wireless sensor network and can be used in backtracking errors that have been noticed in the network. The energy cost of the neighbourtables will be studied more specifically for all the ported platforms.

Acknowledgements

The work presented in this paper was supported by LuTek-project, funded by the Regional Council of Central Ostrobothnia and European Union structural funds.

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