Data Gathering Model for Wireless Sensor Networks Based on the Hierarchical Aggregation Algorithms for IP Networks

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Summary
The paper deals with the data gathering in the sessions with the large number of end nodes. This situation can be represented by the networks with the IPTV service or by the monitoring process in the large-scale wireless sensor networks. The main aim of this paper is to propose and investigate the implementation of the Tree Transmission Protocol for IP networks into the restricted wireless sensor networks.

Key words:
Clustering, data gathering, hierarchical aggregation, tree transmission protocol, wireless sensor networks

1. Introduction

With the emerging application feasibilities of the wireless sensor networks (WSNs), several efficient algorithms and protocols proposed for the IP networks could be applied with some modifications into these energy and bandwidth restricted micro sensor networks. With the growing number of Internet users, the recent research in IP networks is devoted to the effective communications in the large-scale IP networks. Suitable example could be the issue of the IPTV applications with the huge numbers of receivers taking advantage of the RTP/RTCP protocol. In accordance with the RTP/RTCP specification [6], the receivers send in the periodic interval report messages to inform the IPTV server about the quality of the multimedia content receiving. In this report, the information about the delay, jitter or packet loss is transferred. It is obvious, that sending side needs to receive this information with the shortest delay to react at the unexpectedly complaints in the network. In accordance with the specification [6], the feedback report interval is linearly dependent on the number of receivers. Therefore, with the growing number of receivers in the given session, the report interval reaches the unusable values. To settle this issue, several approaches optimizing time delay of the receiver's reports were proposed. The TTP protocol was recently proposed to outperform the mentioned issues and its performance is investigated further. In the WSNs, we battle with the similar issue. Since the WSNs are composed of the high number of narrow sensor nodes, the optimization of the energy-intensive data reporting process becomes the manner that need to be effectively solved. For the future, there is a considerable effort to merge the quite different networks such as the IP and WSN networks and that is why, the several protocols for IP networks could be successfully applied to the WSN environment. Hence, we consider applying the efficient TTP protocol for hierarchical data aggregation in IP networks to the WSN environment, where it can serve for the energy-efficient data gathering from the large-scale sensor networks. The rest of paper is organized in the following manner. Chapter 2 describes and evaluates the performance of the proposed TTP protocol. In the chapter 3, the most known routing protocols for the WSNs are summarized. In chapter 4, we define the limitations of the TTP for the implementation to the WSN and in chapter 4, the radio energy model of WSN is evaluated. The chapter 6 brings the conclusion and the future work.

2. Tree Transmission Protocol – TTP

To outperform the issues mentioned above, we have developed a new protocol referred as TTP (Tree Transmission Protocol) [2] [3] ensuring the creation and management of the effective hierarchical structure for large-scale IP sessions. TTP allows the transmission of great data volume in the short times through the relatively narrow links. It utilizes the centralized approach together with the summarization mechanism to gather a data from the large number of nodes. If the number of nodes exceeds the certain threshold, the summarization is performed in more aggregation levels. However, to completely apply our protocol, several new components need to be engaged to the given network (see Fig. 1). Basically, the end nodes

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(rcv) need to find out its geographic position (coordinates) to determinate to which summarization node send data. Application running at the end node uses the GNP (Global Network Positioning) [4] and Vivaldi [5] algorithm to estimate the correct geographic position of the given node. The position ranging is performed by means of the Landmarks (LM) whose position is well-known to all nodes. The RTT (Round Trip Time) counted by means of the ICMP messages was determinate as the basic metric for the position estimation. When the location process is done, all end nodes send own geographic coordinators to the FTM (Feedback Target Manager) that computes the optimal hierarchy of the summarization nodes FTs (Feedback Targets). The form and capacity of this hierarchy structure illustrated in Fig. 2 is based on the session conditions announced by the sender (S). The root of the whole structure situated in level 0 is the Root Feedback Target (RFT), common FT node that communicates directly with the S. This S could be represented by the IPTV server in case of the IPTV session.

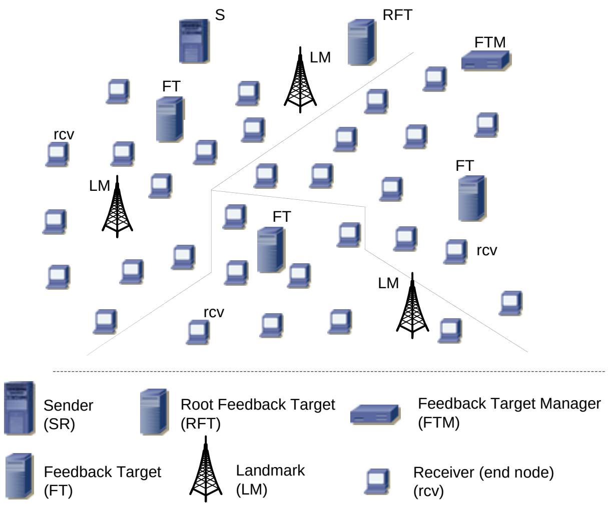

Fig. 1 Network components needed for TTP architecture

The S requirements include the demanded bandwidth for the given multicast session and the assumed number of clients interested in the session. We have used the formula (1) to compute the number of necessary levels $H_{FT}(n)$ (see Fig. 2) for the specific number of end nodes. Parameter n stands for the number of nodes. The S requirements include the demanded bandwidth for the given multicast session and the assumed number of clients interested in the session. We have used the formula (1) to compute the number of necessary levels $H_{FT}(n)$ (see Fig. 2) for the specific number of end nodes. Parameter n stands for the number of nodes.

Obviously, $H_{FT}(n) = 1$ for the number of receivers less $N5$ parameter that stands for the number of receivers for which, the feedback interval does not exceed the 5 secs threshold defined according to RTP/RTCP standard.

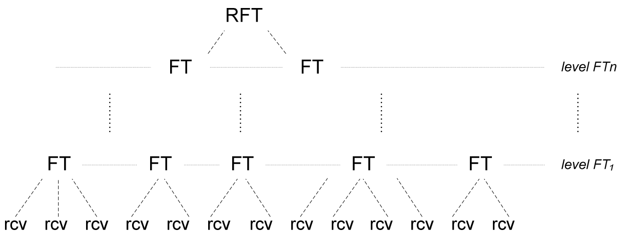

Fig. 2 Hierarchy structure of FTs

In accordance with the formula (2), we are able to determinate the number of the FTs for the each level of the HA tree. Here, the n parameter stands for the number of leaves in the next lower layer.

$$H_{FT}(n) = \begin{cases} 1 & : n \le N_S \\ 1 + H_{FT}(n/N_S) & : n > N_S \end{cases} \quad [-] \tag{1}$$

$$L_{FT}(n) = \lceil n/N_S \rceil \quad [-] \tag{2}$$

From the formula (1) and (2), we calculate the total number of FTs for the whole session, see formula (3).

$$N_{FT}(n) = \begin{cases} 1 & : n \le 0 \\ L_{FT}(n) + N_{FT}(n/N_S) & : n > 0 \end{cases} \quad [-] \tag{3}$$

The results from the Matlab simulation were obtained for the following network conditions:

Session bandwidth	….	4 Mbps
Report interval	….	5 sec
Size of report message	….	480 b
Size of aggregated message	….	8000 b
Number of end nodes	….	10^6

As one can see in Fig. 3, there could be just only one HA level for the network scale of 1000 end nodes. When this number grows up, the creation of the multilevel tree is necessity. For the session with the 1 million end nodes, the HA tree needs to be organized into the three levels e.g.

FTM maintains the set of FTs and forms them to the hierarchical tree structure. Thus the FTs can transmit information from a huge number of receivers to a single node (RFT) in very short time when compared with RTP/RTCP standard. FTM also monitors the number of nodes and when needed, it updates the hierarchical tree structure. As the algorithm is proposed to use a constant bandwidth, when a few receivers are connected, e.g. on start of the session, it could lead to send the reports too often. Therefore a good idea is limit the lower bound by 5s. This constant is also used in RTP/RTCP standard

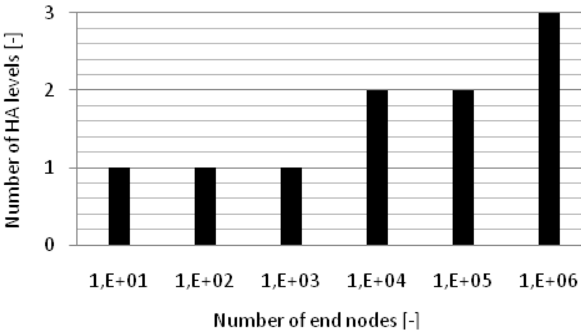

Fig. 3 Dependency of the number of HA levels on the number of the end nodes

To use the TTP protocol for the efficient data gathering from the large-scale sessions one need to know, where to properly place the reference points LMs. To settle this issue, we have implemented the “Global Network Position” [1] JAVA application simulating the GNP and Vivaldi algorithms (mentioned above) for the determination of the optimal LMs placement. We have performed the simulation of our approach in the Matlab, where we have investigated the dependency of the time-interval reports on the number of the HA tree levels. Furthermore, we have compared the obtained results with the DT (Direct Transmission) approach, where all nodes send reports via the unicast channel directly to the S. This DT approach is used in nowadays IPTV sessions e.g. the simulation conditions were kept same as in the first investigation.

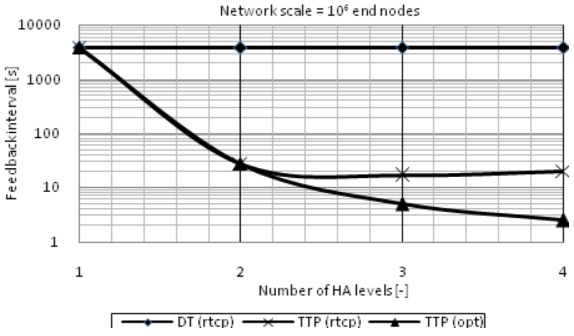

Fig. 4 Optimization of the feedback report time with the growing number of the HA levels. And comparison with the common DT approach.

For the DT approach, the number of the HA levels does not affect the final feedback interval, since the reports are transmitted via unicast directly to the S. This interval was calculated according to RTP/RTCP specification in [6]. Hence the feedback interval remain constant at the value of 3834 sec. To ensure the certain quality of IPTV session, this feedback interval is absolutely deficient. Next, we have evaluated the two approaches for the efficient data gathering based on the TTP model. The efficiency in terms of the feedback interval of two structures referred as the TTP_{RTCP} and TTP_{OPT} were compared. In the TTP_{RTCP} structure, the feedback interval of report sending is set according to the RTP/RTCP specification at the 5 sec. This interval is applied at the rcv level (see Fig. 2) while the report interval in the rest of the FT hierarchy is calculated in dependence on the number of the FTs in each level. One can see in Tab. 1 that with this TTP_{RTCP} structure the 3-level hierarchy is constructed for the session with the 10^6 receivers. Feedback interval optimized by means of this approach is reduced at the 17 secs. In the second TTP_{opt} structure illustrated in Fig. 4, the feedback interval at the rcv level is decreased under the 5sec threshold at the cost of the FTs number increasing in the higher level. For 1 million receivers, 3834 FTs nodes needs to be established in the first FT level (see Tab. 1). We can observe, that the 4-level structure of the TTP_{OPT} is able to reduce the feedback interval at the value of 2,5 sec. Thus, this approach absolutely outperforms the feedback intervals calculated by the DT model of data gathering used in the nowadays large-scale IP sessions.

Tab. 1 Number of particular FT nodes for each level of the HA tree

HA level	FT (TTP_{RTCP})	FT (TTP_{OPT})
1	150	3834
2	7	115
3	1	11
4	-	1

TTP protocol is more complex and its comprehensive description is out of this paper scope. For more information see [1].

3. Related Work for Data Gathering in WSN

Energy issues of WSN applications attach importance on utilized data routing mechanism. Using of the traditional routing protocols proposed for ad-hoc wireless networks [8], [9] runs up against specific WSN characteristic such as data centric approach, application specific requirements, local data correlation and nodes without its global unique IDs. That is why the WSN routing protocols have to meet different requirements (application specific, data centric, energy-aware, data aggregation capability). This chapter summarizes the most known routing protocols in WSNs using certain type of hierarchical aggregation processes.

The hierarchical data gathering and aggregation model for WSNs was firstly introduced by Jiang et. al in [11]. In this model, a coverage area of the sensor nodes is divided into overlapping clusters and data from each cluster are sent towards the base station through a specific node called Cluster Head (CH) taking care about the data aggregation from ambient nodes. All nodes in the specific cluster send its measured data to assigned CH performing the summarization and aggregation tasks and transmit an aggregated message (referred as the data histogram) to another CH or directly to the base station. The TEEN, APTEEN, PEGASIS, LEACH and its modifications are the representative of this routing approach and they are described further. Hierarchical routing protocols can be further classified according to the clustering algorithm as the distributed protocols, LEACH (Low Energy Adaptive Clustering Hierarchy) [12], HEED (Hybrid Energy-Efficient Distributed clustering) [13] and centralized protocols, LEACH-C (LEACH-Centralized) [14] and BCDCP (Base-station Controlled Dynamic Clustering Protocol) [15].

The LEACH protocol was proposed by Heinzelman et. al in [12] as a first energy-efficient hierarchical algorithm for wireless sensor networks. Now it stands for the most popular WSN routing algorithms. The LEACH operation is divided into the time rounds. LEACH forms clusters in the whole network and elects the CH at the beginning of each round. Other nodes in the cluster subsequently subscribe themselves to the concrete CH. When the subscription process is done, the CH broadcasts the TDMA schedule that assigns a time slot to each node. After the CH receives data from each node, it processes gathered data and transmits aggregated information toward the base station. Since to be the CH spends a considerable amount of energy (caused by data processing and transmitting to the far distances) its role is rotated among all nodes in each cluster. The CH election is performed in the first phase (set-up phase) of the round where the nodes elect itself to be the CH [12].

$$T(n)=\frac{P}{1-P\left(r \bmod \frac{1}{P}\right)},\ n\in G \qquad (4)$$

$$T(n)=0,\ otherwise$$

Each node generate the random number <0;1> that is compared with the threshold value *T(n)* computed in accordance with the formula (4). If the random number is less than the threshold *T*(n), the appropriate node acts as the CH for the current round. In the formula (44), *P* stands for the percentage of the clusters in the sensor field, *r* is the current round and *G* is the set of non-clusterheads in the last 1/*P* rounds [12]. The percentage of the clusters is established in terms of the network density and topology and the cost of the computation and communication. Authors of [12] have defined the optimal value of *P* = 5%. Since LEACH does not guarantee an efficient deployment of CHs, an enhanced protocol called LEACH-C was developed [14]. In comparison to LEACH, it differs only in set-up phase; the phase of data transmission remains unchanged. A CH election is held in a base station. Each node sends information about its current location and remaining energy level to the base station node that subsequently forms the optimized clusters with its CH using simulated annealing algorithm [16] to solve NP-hard problem.

The LEACH-F (LEACH-Fixed cluster) [14] is another LEACH modification. LEACH-F as opposed to LEACH forms the fixed clusters with the CH position rotation. The main idea is to save energy in the set up process. The clusters are formed only in the first time using LEACH-C algorithm and then only the position of the CHs is changed. However, the LEACH-F is quite impractical since it does not provide scalability and ability to adjust its behavior when the nodes become dead. And that is why; it does not find any concrete utilization in WSNs.

The above mentioned LEACH based protocols consider specific system parameters and single hop communication inside the clusters. But in general, there can be system conditions that would have better energy consumption results with multi-hop communication. Therefore, the M-LEACH (Multi-hop LEACH) was proposed [16].

When the network operates in a reactive mode the TEEN (Threshold sensitive Energy Efficient sensor Network) protocol [12] could be applied. It is a protocol designed for an application where the nodes sense continuously theirs environment and transmits data only when measured value reaches the given hard threshold specified in the initial setup phase. There is another threshold called the soft threshold that is compared with the difference of the subsequently measured values. When the difference is higher than soft threshold and consequently the last measured value is above the hard threshold the node sends alert message to the base station. APTEEN (Adaptive Threshold sensitive Energy Efficient sensor Network protocol) is an improvement to TEEN and enhances the function of TEEN by periodic data collecting. The Directed Diffusion paradigm in WSN [18] is a different approach in field of data fusion techniques. It is based on a query from a base station to get information about specific interest and its location. The interest is defined according to a selected naming-scheme and is diffused through the sensor network.

4. TTP limitations for Wireless Sensor Networks

We have proved that TTP works well for efficient data gathering in the environment of the large-scale IP sessions0. But, it is obvious that this protocol designed for the IP networks cannot be implemented to the WSN environment without the crucial modifications. Hence, we have to retransform the feedback delay optimization of TTP to the energy-efficiency optimization manner of the TTP/WSN to prolong the sensor network lifetime.

The computing and communications capabilities of the IP networks are many times powerful than the facilities of the restricted wireless sensor networks. In WSN, we have to battle with the restriction in terms of the energy supplies, the narrow bandwidth and the constrained computing processes. To go ahead, the main conditions of the WSN environment need to be defined. We consider a homogeneous network where all nodes have the same communication and computing capabilities together with the same level of the energy reserve. At this point we turn aside from the described TTP network structure, where the aggregation FT nodes are more powerful than the end nodes. Since the aggregation process consumes the considerable amount of energy, the function of the aggregation nodes referred in WSNs as the CHs (Clusterheads) needs to be rotated among all nodes. This rotation process is necessary for spreading out the energy-load of the aggregation process and thus to retain the same energy-level of all nodes in the sensor field. Furthermore, as we show later in the chapter 5, the communication in WSN is the fundamental energy consumer. From this reason, the number of transmission during the initial network configuration and data collecting process need to be kept as low as possible. Hence, the TTPs centralized approach must to be retransformed to the distributed manner to reduce the communication with the base station (BS) that controls the structure of the created HA tree and thus to prolong the network lifetime. BS maintains the form of HA tree, but we try to force sensor nodes to be self-organized as much as possible. For example, when the sensor field will be expanded with a new set of nodes by the human intervention, this set needs to join itself to the existing HA tree with the minimum BS cooperation. The dynamic form and structure of the WSN and TTP tree is the common behavior for the both environment and thus the proposed algorithms for TTP tree could be partly used in the WSN case. However, the often changes in the number of sensor nodes are not expected.

In the TTP protocol, all nodes locate own geographic position by means of the triangulation algorithms by the focusing at the LMs reference points. Most of the protocols mentioned in the chapter 3. suppose the location awareness sensor nodes in scale of thousands or millions. However, these expectations are rather out of the reality. GPS equipped nodes are very expensive and their considerable energy consumption is also a big drawback. Hence, these GPS equipped nodes are not suitable to deploy in the large-scale low-cost WSNs. Our approach it to investigate the WSN in the scale of up to 1000 nodes that will use the GNP [4] and Vivaldi [5] algorithms to determinate own position in the sensor field. As we described above, to find out own position the end nodes in TTP measure the RTT parameter toward the LMs. In WSN, the similar approach could be used. We assume the random deployment of sensor nodes with the certain prediction of nodes position. From this assumption, we are able to pose the definite number (3 minimally) of reference nodes (referred as RN) in the specific location. The energy supplies of these RNs will be sacrificed to act as the landmarks for the rest of sensor nodes computing own geographic position by means of them. These RNs that serve just only for the localization process receive a great amount of queries and thus they die earlier than the other common nodes. The RSSI (Receive Signal Strength Indication) and LQI (Link Quality Indicator) could be used as the metric for the localization process. In future, we suppose to investigate the energy consumption of this approach via the ns2 simulations and the real measurement in the BENS laboratory (Brno - Experimental Network of Sensors), experimental sensor network containing 100 sensor nodes Crossbow MicaZ [7].

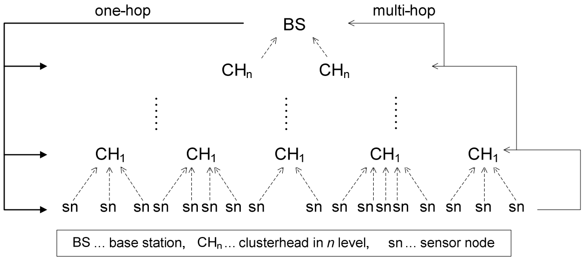

Fig. 5 Hierarchical structure for TTP-WSN extension. Base station communicates directly with all nodes in sensor field wheras the sensor nodes use the multihop communication to reach the Base station.

As well as in the TTP model where the FTM is able to communicate with the all nodes of the session, for the TTP -WSN extension, we consider the asymmetric communication where the BS is capable to communicate directly (by one-hop) with all nodes in the sensor field whereas the nodes are capable to reach the BS via the multihop transmission. This situation is denoted in Fig. 5. Since the sensor network is divided into the several clusters where for each cluster one specific node acts as the clusterhead, for the far-away clusterheads is energy-uneconomical to transmit aggregated data directly to the BS. Hence, we consider using of the multihop communication for the CHs or as well as in the TTP model, to form the multilevel hierarchical tree where data will be aggregated in the multilevel hierarchy of CHs (see Fig. 5). During our investigation and designing of TTP-WSN extension, we would like to combine the basics of the TTP and LEACH algorithms. Nevertheless, in contrast of the LEACH we assume the forming of the fix clusters being constructed just once at the beginning of first data gathering process, such as the LEACH-F. In the case of the WSN expansions with another set of sensor nodes, then the clustering process will be performed again. The new nodes announce to the BS that performs the re-clustering process.

5. Investigation of Radio Energy Model

To investigate the energy-efficiency of the proposed TTP/WSN protocol, it is necessary first of all to evaluate the energy-cost of the fundamental communication processes such as the transmission and receiving processes of the sensor nodes. To fulfill these requirements, we have described the energetic mathematical model and consequently performed the real measurements with the MicaZ motes [7].

For the description of the mathematical model, the first order radio model from [12] was used. This model is illustrated in Fig. 6.

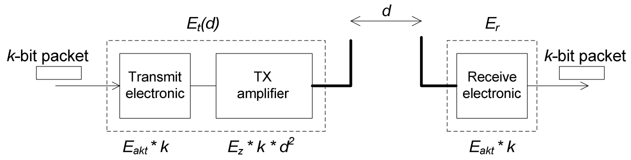

Fig. 6 First order radio model (redrawn from [12])

To transmit the message with the size of k bits, it is necessary to consider the energy consumption of the transmitter and receiver circuits' activation E_{elec}, as well as the energy cost of transmit amplifier E_{amp} to reach the acceptable E_b/N_0 [12]. During the transmission it is necessary to assume the energy loss r^2 due to the channel propagation. Thus to transmit k bit message to the distance d, the radio interface consumes amount of energy calculated according to formula (5).

$$E_{TX}(k,d) = E_{TX-elec}(k) + E_{TX-amp}(k,d) = E_{elec} * k$$

The calculation of the energy consumption of the receiving process is the less exigent and it can be calculated according to formula (6).

$$E_{RX}(k) = E_{RX-elec}(k) = E_{elec} * k \qquad (6)$$

In the next paragraph, the energy consumption of the communication processes in the real wireless sensor network is investigated.

WSNs are based on IEEE 802.15.4, a layer 2 protocol designed for Personal Area Networks (PAN) composed by limited devices. However, sensor nodes are more limited yet, than conventional devices, being the main issue the energy consumption. In order to optimize this question, guaranteeing an extra life time for each sensor node, many protocols have appeared to optimize the duty cycle. Duty cycle is composed of two stages, first one where the sensor node is sleeping to save the energy, and another one where it wakes up only to send or to receive appropriate messages. These protocols are quite complex but theoretically they are indispensable. At the moment many protocols were presented, simulated, but just a few implemented successfully. IEEE 802.15.4 protocol allows natively the management of duty cycle. In [19] its operation is analyzed. Many studies have been performed in order to save energy, but the major consumer of the energy supplies is the radio communication. In this section, we present the real consumption of MicaZ mote with an MDA100CB sensor board, running Tiny OS-2.x in different scenarios. The experiment scenarios are denoted in Tab.2.

Tab. 2 Parameters used for the energy consumption experiment

Evaluation No.	Protocol used	Packet size	TX interval
1	IEEE 802.15.4	10 B	5 s
2	IEEE 802.15.4	36 B	5 s
3	IEEE 802.15.4	45 B	5 s
4	IPv6	45 B	5 s
5	IPv6	129 B	5 s

Evaluation 3 and 4 uses the same packet length and they were performed purposely to compare the differences between IEEE 802.15.4 and IPv6 transmission consumptions. The IPv6 stack was successfully implemented to the TinyOS by the 6lowPAN research group [20]. To achieve the size of 45 bytes in IEEE 802.15.4 it was necessary to tune the protocol in order to support an active message with a payload greater than 28 bytes, in this case with the 37 bytes of payload. Evaluation No.5 was performed to investigate the impact of the large packets in 6lowPAN, forcing fragmentation, which means two packet sent per message. In this case, at layer 2, there was received one packet with 108 bytes more than another packet with 21 bytes to construct the message at the

6lowPAN layer. Fig. 7 presents the consumption in one hour of each evaluation. Two AA batteries from Varta (2 x 1,5V) were used as the power supply. This kind of the supply was not changed during of all evaluations.

By the investigating of the Fig. 7 trends, it is possible to observe that the three last cases consume more energy than the two firsts. It is also possible to see, that the last one was the most expensive. The final results obtained as the difference of the initial and end voltage-level are illustrated in the Fig. 8.

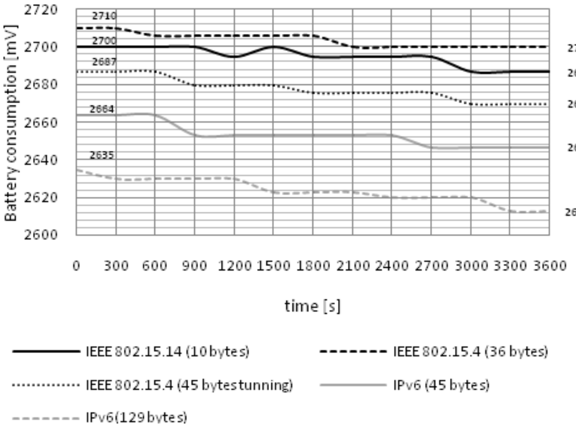

Fig. 7 Energy consumption at the begin and the end of the experiment for the different size of message.

We can conclude that if the common IEEE 802.15.4 packet length is used, the battery consumption is almost same. However, if the CC2420 definition is changed, in order to support an extra large packet with a payload greater than 28 bytes, it consumes as much energy as the test with IPv6. We can also conclude that IPv6 for the same packet size, i. e. 45 bytes, consumes almost the same energy as the tuned IEEE 802.15.4.

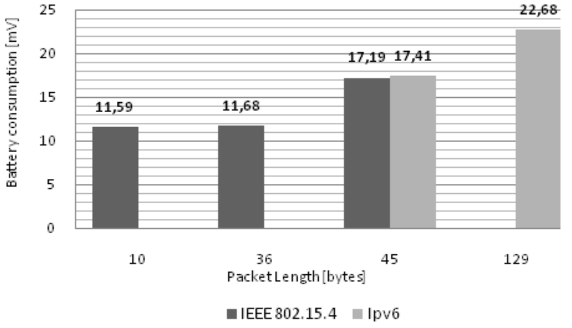

Fig. 8 Energy consumption per hour/bytes

However, it is a quite superior to the normal IEEE 802.15.4, which is traduced in the complexity of IPv6. If we use a large packet of IPv6 i. e., forcing fragmentation, the battery consumption increases significantly. Knowing that in one hour 3600/5 = 720 messages were sent, we can present the results listed in Tab. 3.

Tab. 3 Energy consumed for different message size

Protocol	IEEE 802.15.4			IPv6	
Message size [bytes]	10	36	45	45	129
Volts/message [µV]	16,09	16,22	24,29	24,18	31,5

Tab. 3 Energy consumed for different message size resumes the consumption per message in one hour of operation for all evaluations. By the values observation, the difference between each case becomes evident. For instance, the same application for IEEE 802.15.4 sending a 45 bytes packet spent more energy than a 36 byte packet, and the difference in packet size is not so evident. However, the same results were not appeared between the experiments with the 10 and 36 packet length, since the difference of packet size is not considerable, thus the divergence of the energy spent is not relevant for experiments samples with the length of one hour.

Since we have proved that there is no considerable difference between the energy consumption of the transmission process of the IEEE 802.15.4 and the IPv6 protocol, we have performed the second experiment to evaluate the cost of the receiving process with the IPv6 protocol. During one hour, the one MicaZ mote was programmed to receive one 45 bytes message per 5 seconds. Simultaneously, this mote reported its battery level each 5 minutes. The obtained results are illustrated in Fig. 9.

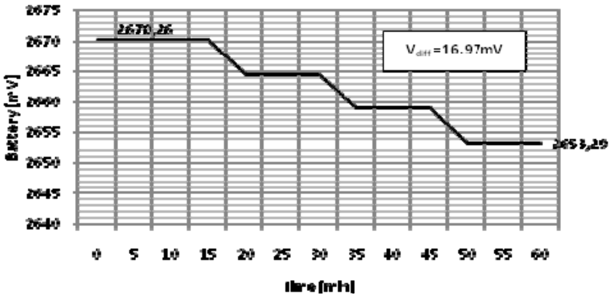

Fig. 9 Energy cost of the one hour receiving process of the 45 bytes message received each 5 seconds. Protocol used: IPv6.

From the obtained results, the real cost of receiving process of one 45 bytes message can be calculated. The voltage-value depleted during 3600 seconds experiment was *diff* = 16,97 mV. Since the message was received each 5 seconds, we can calculate the cost C_{rcv} of the one message receiving according to formula (7):

$$C_{rcv} = \frac{V_{diff}}{t} \times mi = \frac{16{,}97}{3600} \times 5 = 23{,}5\ \mu V \tag{7}$$

The V_{diff} parameter stands for the voltage difference of trend in Fig. 9, t is the time of the experiment and mi parameter represents the message receiving interval. From this result, one can observe that the cost of the receiving (23,5 µV) and the transmitting process (24,18 µV in Table 3) reaches nearly the same values.

6. Conclusion and Future Work

In this paper, we have investigated the efficiency of the Tree Transmission Protocol for the effective data gathering in the time manner that could be successfully used in the IP networks with the IPTV service e.g. We have proved, that TTP protocol is able to outperform the present RTP/RTCP standard used for the IPTV applications. Since the TTP protocol obtains the successful results, we have proposed its extension to the WSN environment, where the time-delay optimization needs to be re-transformed in the energy efficiency manner to prolong the sensor network lifetime. To accomplish this, the fundamental radio energy model needs to be defined together with the real measurement in the sensor network to obtain the solid values for the future investigation. In the future work, we plan to implement the TTP protocol to the network simulator 2 and evaluate its performance in the WSN environment. Furthermore, we assume the implementation of TTP/WSN extension into the real sensor network that is situated in the BENS laboratory to evaluate the proposed protocol in the real WSN environment.

Acknowledgments

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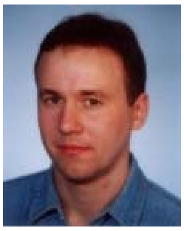

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