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Optimizing Computations in Intermittently Powered Wireless Sensor Nodes

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***Abstract*—** Communicating man and machine is always beneficial when their linkage is for information exchange. Information Communication Technologies (ICT) thus seek for such technologies and communication schemes where it can eliminate the use of frequent, time to time re-programming as well as charging/ topping up the battery resource. For the same purpose, researchers are always into the development of such Wireless networking based schemes where the battery constrains are minimized. Internet of things (IoT) is one of these emerging technologies. This research focuses on the implementation of IoT based techniques to minimize the battery re-charge time by studying the behavior of motes (Nodes in IoT) with respect to its information exchange, network throughput and power management. The research uses capacitor driven motes that can accept data wirelessly and transmit it directly after its reception or can restart the mote while the data is being preserved in its Read only flash. There different scenarios have been sequentially analyzed for incremental number of nodes from 2 to 15, whereas the capacitance is calculated for nominal data transfer. The results conclude that once the deployment of the network goes from scares to densely populated network, the charge due to the mode's capacitance exponentially optimizes. The research concludes that lower number of nodes must be greater in order to use higher capacitance values whereas lower network density must follow the strategy of broadcasting its data without writing it on Read only flash memory.

***Keywords*—** Internet of Things, Wireless Sensor Networks, Intermittently powered nodes, Power analysis of communication.

I. Introduction

This document concentrates on power/energy profiling of wireless sensor nodes in wireless networks. In wireless sensor networks, the wireless nodes energy is restrained resource. Engineers and Scientists worked hard to optimally utilize the available energy. But on every passing moment; the energy requirement is increase due vast range of newly develop application of WSNs. Internet of Things (IoT), is rising concept of Wireless Sensor Networks. In IoT, the number of wireless sensors nodes ranges from hundreds to tens of thousands are distributed over the desired locations for in demand applications. The wireless sensor nodes are also called motes. These motes must have some energy resource for their essential functions and this energy resource should be utilized efficiently. The number of method use for increasing the energy consumption efficiency of these motes likely CRFIDs [1], Computational RFIDs, reduce power consumption of motes by modulating the reflection of power uttered by an external transmitter instead of transmitting actively. The general purpose battery less sensor devices [2], is micro controller based devices which harvest energy from environmental factors, for example sun light, vibration etc. Energy harvesting system [3] energized itself by harvesting energy of its surroundings. The energy is mostly temporarily available, offering intermittently supply or power resource. As the energy vanish, the processor turn off. The processor start up again as soon power available, but also restart computations. Hence, difficult for motes to complete necessary computations.

As per Internet of Things application requirements, the motes have possible minimum energy storage capability to serve in medical implants [4] and smart dust. Mememtos [5] is relatively recent development which place Watchdogs/checkpoint [6] in pre execution (Compile) time. Momemtos save volatile memory to non-volatile memory just as voltage level drops threshold value (pre-determined value). Herbenus [8]; in this mechanism the device or mote swing between two states: active state and hibernating state. The hardware interrupt for swing between two states is define by threshold voltage. The device store last setup or necessary information on nonvolatile memory prior to shifting hibernating state.

II. Literature Review

WSN network are employed to optimize industrial processes, autonomous control, vehicular and non-vehicular traffic, health care application and its improvement, and various surveillances system etc. Till date, major industrial manufacturer has deployed more than 30,000 networks across the world to improve safety and process efficiency in different locations. These industries are ranging from beverage and food plants to oil refineries and production facilities [7].

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A. Wireless Sensing in IoT

The sensor network is the key to Internet of Things and big data support. Sensor networks require to transmit sensed data to sink or some central processing unit. The mote may send data to central processing unit directly if it is lying within mote wireless transmission range. Else, it may convey its acquired data indirectly via intermediate mote using multi hop transmission. Multiple ad-hoc routing protocols have been proposed in [8]. In all these ad-hoc routing protocols, it is assumed that all motes are active all the time. In IoT, motes are commonly in sleep mode instead of activity. It is employed for saving the scarce energy resource that is equally contrary to the research assumption in [8]. As mote communication modules work only in active state, it is essential for successful multi hop communication in network that all intermittently power motes are in active state. Therefore, intermittently powered motes communication protocols are being dealt further for their proper categorization.

B. Synchronous and Asynchronous connectivity

The protocols are devised into synchronous and asynchronous communication protocols. Traffic Adaptive Medium Access Protocol (TRAMA) [9] and Lightweight Medium Access Protocol [LMAC] [10] are synchronous protocols. In synchronous protocol all motes communicate the control data signals. In asynchronous Intermittent Receiver-Driven Data Transmission (IRDT) [11] protocol, the mote delay its transmission for the next hop neighbor mote to be active without continuous transmission of control messages [11]. In Low Power Listening (LPL) [12] Protocols, motes wastes a significant amount of energy on communicating control messages. Thus it can be concluded that, in intermittently power mote communication protocols, the throughput and energy consumption are the figure of merits. The superficial sleep mode that is the key feature of a mote, in its advance transmission protocols that includes synchronous, asynchronous and event driven based radio switching protocols needs to be evaluated [10].

III. EXPERIMENTAL SETUP

Low Power wireless network becoming essential part of our daily life. The figure of merit is power consumption of these devices, but measurement of power consumed by these mote is challenge. In Contiki operating system, Powertrace is network level power profiling module. The powertrace module can be used for both; simulation like cooja, and hardware. According to experimental results, it had been proved that their result is 94% accurate.

A. Sensing Investigation depth

For in depth investigation of power consumption of wireless sensor mote at network level, powertrace is optimally best tool used in contik-3.0[13]. The skymote telosB module emulator is use in the experimental setup developed in contiki-3.0. The selectivity of telosB module is easy availability in market with low prices. Most of research community is using the above said hardware due to multiple flexibilities, but here its discussion is out of scope.

a) Power trace

For in depth investigation of power consumption of wireless sensor mote at network level, powertrace is optimally best tool used in contik-3.0.

- ALL_CPU: the amount of power consume in active mode of CPU.
- ALL_TX: total number of ticks in transmit state.
- ALL_RX: total number of ticks in receive state.
- ALL_LPM: total number of ticks in Low Power mode.

$$E_c = \frac{Energest\ Value \times Current \times Voltage}{RTIMERSECOND \times RunTime} \qquad (1)$$

Where Ec is referred to as the Energy consumed by node. Current & voltage are referred from data sheet solve an example.

$$Duty\ Cycle = \frac{Energest\_TX + Energest\_RX}{Energest\_CPU + Energest\_LPM} \qquad (2)$$

Mesh networking and broadcast is most common practice for WSN network and especially for IoT base applications. Numbers of simulation were performed to identify the power profile of the motes in network. The number simulations were performed in cooja (contiki-3.0) by varying the number of motes and their topology.

The simulation time and code model (mote-programming) are kept same for ease in comparisons. The contiki-3.0 includes number of hardware emulators. I opted sky t-mote for simulation in contiki-3.0. T-mote sky [14] is low power sensor module. It can be used for various kind of sensor network application; like monitoring applications or may be for application prototyping. T-mote upgrade industrial standards by addition of USB and seamlessly interoperability with other devices. T-mote sky support multiple application of wireless mesh network and open source software movement in addition.

b) Features

Dealing the structural and functional characteristics, ST M25P80 40MHz serial flash code memory is part of sky t-mote module as external memory for code storage. The flash memory are 16 segments, each having 64KB in size, shares SPI communication lines with CC2420 transceiver. Flash memory (48KB) is available for data and code storage in sky t-mote module. The flash or microcontroller are programmable when the voltage is at least 2.7volts.

c) External Flash

ST M25P80 40MHz serial flash code memory is part of sky t-mote module as external memory for code storage. The flash memory are 16 segments, each having 64KB in size, shares SPI communication lines with CC2420 transceiver. Flash memory (48KB) is available for data and code storage in sky t-mote module. The flash or microcontroller are programmable when the voltage is at least 2.7volts. The mote can be used without battery module if it is connected to the computer via USB. The functioning voltage is 3 volts when USB is plugged in to computer. Table I has typical operating conditions for operation of read/write and erase operation with external flash memory via communication with SPI share with the radio communication.

B. Setup 01

In this simulation setup, wireless communication of sensor nodes are blocked. Only writing and reading of flash memory (available in T-mote sky module) are performed. The powertrace application is used for calculation of energy consumed by the mote for performing the above said activity. This is for the accurate measurement of energy consumed by flash operation only. In other words, it simplifying calculation by not considering all energy, i.e. energy consume by initialization of mote, consumed by motes except flash memory operation. The energy consumed by mote for writing/reading of flash memory is independent of network setup, number of nodes and communication protocols.

TABLE I. CHARACTERISTICS OF MOTES

Device characteristics	**Minimum**	**Nominal**	**Maximum**
Supply voltage during flash memory programming (v)	2.7	n.a.	3.6
Erase/Programming cycle (CPS)	n.a.	n.a.	100,000
Active Current (READ) (mA)	n.a.	n.a.	4
Active Current (WRITE/ERASE) (mA)	n.a.	n.a.	20
Standby Current (mA)	n.a.	8	50
Deep Power down Current (mA)	n.a.	1	10

C. Setup 02

The objective of this setup is to analyze the energy consumed by nodes/motes (T-mote sky module) by wirelessly communicating with different nodes/motes. For wireless communication between motes, broadcast protocol is used. The number of nodes are different in different simulations. The position of nodes are random, but multiple nodes are in range with other multiple motes. The network is simulation for fifteen minutes. The simulation result may be analyzed against different parameters discussed in coming sections.

IV. SIMULATION

The simulations are analyzed for the two setups studied. Each one is explained in detail as under.

A. Setup 01

Table II collects the result of simulation of the writing & reading of flash memory of T-mote sky module. First column represents time of call of powertrace application, Second energest and third one is just remarks regarding operations.

a) Calculated Results

We have calculated the energy consume by sky t-mote by erasing, writing and reading of external flash memory in this section.

TABLE II. SIMULATION RESULTS OF READ/WRITE OPERATIONS

Time of Operation	**CPU (Energest)**	**Remarks**
00:05.702	2040	Just Before Operation
00:06.702	5665	Just After Operation

Consumption is 3588.25 m-Joule.

b) Energy consumed by writing/Erasing

Writing to flash operation memory is accompanied by erasing the flash operation. Both operations withdraw 20-mA current. The calculation is performed at lowest, average and peak/maximum possible voltage level as shown in Table III.

TABLE III. CALCULATED RESULTS FOR ERASE/WRITE OPERATION

Energy parameters for the following Operations	**Voltage (V)**	**Estimated Energy (mJ) @20mA Current**
Maximum energy estimated for Writing Process	3.6 (max.)	3240
Average energy estimated for Writing Process	3.15 (avg.)	3240
Minimum energy estimated for Writing Process	2.7 (min.)	3240

c) Energy consumed by Reading

The reading from flash memory withdraws current of 4-mA. The calculated results are represented in Table IV.

TABLE IV. CALCULATED ENERGY FOR READ OPERATION

Energy parameters for the following Operations	**Voltage (V)**	**Estimated Energy (mJ) @20mA Current**
Maximum energy estimated for Reading Process	3.6 (max.)	648
Average energy estimated for Reading Process	3.15 (avg.)	567
Minimum energy estimated for Reading Process	2.7 (min.)	486

B. Setup 02

These simulations were performed by varying the number of nodes from 2 to 15 nodes. To differentiate between multiple results, the topic name of simulation result is same to the number of node in simulation.

a) 2 Nodes simulation

This simulation consists of two nodes connecting with radio link. The total, CPU, LPM (Low Power Mode), transmit and receive are represented categorically in Table V.

TABLE V. SIMULATION RESULTS OF 2 NODE SIMULATION

Node Sr. No.	Total	CPU	LPM	Transmit	Recieve
Node ID 1	63.8645	3.618681	0.18556	35.18578	24.87449
Node ID 2	63.4126	3.606071	0.185601	34.82958	24.79135
Average	63.6385	3.612376	0.185581	35.00768	24.83292

b) 3 Nodes simulation

The total, CPU, LPM (Low Power Mode), transmit and receive are represented for 3 nodes connecting on radio link in broadcast in Table VI.

TABLE VI. SIMULATION RESULTS OF 3 NODE SIMULATION

Node Sr. No.	Total	CPU	LPM	Transmit	Recieve
Node ID 1	63.86259	3.618996	0.185559	35.18992	24.86812
Node ID 2	66.03793	3.661529	0.185416	34.8342	27.35679
Node ID 3	65.42726	3.674218	0.185375	36.59353	24.97414
Average	65.10926	3.651581	0.18545	35.53922	25.73302

c) 4 Nodes simulation

The total, CPU, LPM (Low Power Mode), transmit and receive are represented for 4 nodes connecting on radio link in broadcast in Table VII.

TABLE VII. SIMULATION RESULTS OF 4 NODE SIMULATION

Node Sr. No.	Total	CPU	LPM	Transmit	Recieve
Node ID 1	65.68992	3.671949	0.185413	35.19359	26.63897
Node ID 2	68.15268	3.701087	0.185316	34.48443	29.78185
Node ID 3	67.46985	3.714494	0.185272	36.24993	27.32016
Node ID 4	68.92565	3.726176	0.185232	35.1971	29.81714
Average	67.55953	3.703427	0.185308	35.28126	28.38953

d) 5 Nodes simulation

The total, CPU, LPM (Low Power Mode), transmit and receive are represented for 5 nodes connecting on radio link in broadcast in Table VIII.

e) 10 Nodes simulation

The total, CPU, LPM (Low Power Mode), transmit and receive are represented for 10 nodes connecting on radio link in broadcast in Table IX.

TABLE VIII. SIMULATION RESULTS OF 5-NODES SIMULATION

Node Sr. No.	Total	CPU	LPM	Transmit	Recieve
Node ID 1	66.24095	3.670813	0.185386	35.18769	27.19706
Node ID 2	70.88756	3.749253	0.185123	34.48118	32.472
Node ID 3	70.20857	3.770689	0.185053	36.24386	30.00897
Node ID 4	68.13719	3.721932	0.185215	35.19008	29.03997
Node ID 5	68.28231	3.740555	0.185154	36.94972	27.40688
Average	68.75132	3.730648	0.185186	35.61051	29.22498

TABLE IX. SIMULATION RESULTS OF 10 NODE SIMULATION

Node Sr. No.	Total	CPU	LPM	Transmit	Recieve
Node ID 1	74.73757	3.858749	0.184759	36.24545	34.44861
Node ID 2	83.24769	4.011763	0.184248	34.48246	44.56922
Node ID 3	77.56841	3.907865	0.184596	36.24003	37.23591
Node ID 4	73.50033	3.811742	0.184915	34.83802	34.66566
Node ID 5	71.406	3.802726	0.184946	37.29541	30.12292
Node ID 6	75.63848	3.846006	0.184801	34.46987	37.1378
Node ID 7	77.73977	3.885067	0.184671	34.13805	39.53198
Node ID 8	70.99896	3.766749	0.185065	35.14452	31.90263
Node ID 9	71.249991	3.756918	0.185099	34.831329	32.476644
Node ID 10	74.86302	3.845238	0.184786	35.89642	34.93657
Average	73.38383	3.849282	5.706466	32.0091	31.81899

f) 15 Nodes simulation

The total, CPU, LPM (Low Power Mode), transmit and receive are represented for 15 nodes connecting on radio link in broadcast in Table X..

TABLE X. SIMULATION RESULTS OF 15 NODE SIMULATION

Node Sr. No.	Total	CPU	LPM	Transmit	Recieve
Node ID 1	79.31705	3.928555	0.184527	35.53688	39.66709
Node ID 2	90.22996	4.166287	0.183733	34.84025	51.03969
Node ID 3	86.88806	4.089647	0.183989	35.50215	47.11228
Node ID 4	79.02398	3.916029	0.184568	35.18864	39.73474
Node ID 5	75.6609	3.883756	0.184676	36.94351	34.64896
Node ID 6	82.34139	3.996052	0.184301	35.87842	42.28262
Node ID 7	87.35558	4.089152	0.18399	34.4815	48.60094
Node ID 8	78.4809	3.896004	0.184635	35.18498	39.21528
Node ID 9	73.12847	3.780901	0.185019	34.83786	34.32469
Node ID 10	85.21528	4.16158	0.193602	37.29382	43.56628
Node ID 11	88.26998	4.118981	0.18385	35.491	48.47615
Node ID 12	79.34961	3.93306	0.184484	35.52573	39.70634
Node ID 13	83.73351	4.001418	0.184251	35.19549	44.35235
Node ID 14	68.83757	3.709518	0.185245	35.18737	29.75544
Node ID 15	70.41201	3.724667	0.185189	34.12706	32.37509
Average	80.54962	3.959707	0.185071	35.41431	40.99053

V. Results and Analysis

Results for Setup 01 and setup 02 are tabulated and explained in the coming sections.

A. Results of Total energy consumed by complete process for Setup 01

As the simulation time is one second, therefore these simulated results and calculated results are comparable. The comparison of calculated and simulated results are available in Table XI. The table also shows the difference in results in last column. The correlation between the calculated and simulation result is more than 94%.

TABLE XI. COMPARITIVE ANALYSIS

Energy Parameter	Voltage (Volts)	Estimated Energy (mJ)	Simulation Results	Difference (%)
Total Maximum Energy Estimated for Process	3.6 (max)	3888	4110	5.4
Total Average Energy Estimated for Process	3.15 (avg)	3402	3425	5.5
Total Minimum Energy Estimated for Process	2.7 (min)	2916	3083	5.4

B. Results of Total energy consumed by complete process for Setup 02

Energy profile of the nodes that are the part of simulation in setup 02 are given by Table XII. These values are the average of 600 simulations, each with variable data of transmission and reception.

C. Observations

The observation noted are given underneath.

i. As the number of motes increase, the total energy consumption of each motes increase.

ii. The energy consumption of motes in Low power mode and transmit columns are almost the same. Transmission of packet were define at constant periodic period.

iii. The energy consumption of motes by receiving packet shows significant increase because the motes are expected to receive more numbers of packets as the network density increases.

iv. The mote's CPU spend more energy in process of receiving more packet as network population increase.

VI. Discussion

The research summarizes the fact that IoT and sensory network are indeed a great way to communicate chunks of information without wasting a large amount of energy if such discharge based nodes are used. We have used motes of difference capacitances in order to find out the transmission rate and modes of communication. Based on the continuation/resuming of data transmission, the transmission schemes have been devised into three kinds that are; resume and restart, reboot and go to sleep mode and resume. The energy calculation of information exchange is calculated in mJ. The undergone application uses a fixed amount of energy for each restart which suggested that, in order to communicate between these low energy communicating motes, one must reduce the number of restarts instead writing different codes fo already developed application.

The second option is also unique in which we use a resuming mechanism. The resuming mechanism are then devised into two broader types. The first one comprises of OS sleep methods. The application (tiny OS) that is being run on the mote, goes to a power saving mode and the transmission is intermitted. It reduces the energy consumption in the sense that each restart must use energy besides cutting energy from the same reservoir for information exchange. The second option also uses external flash/ROM in order to keep the present state and upon power up the module, all the data is recovered from the ROM. This facility allows the motes to overcome the reboot energy by saving the state of the OS. Such phenomenon can be seen while an operating system is hibernated.

Conclusion

The research conducted acknowledges the resuming mechanism to be more effective. The resuming the motes in internet of things is more advanced and motes uses it instead of restarting or rebooting the whole processing node. As discussed earlier, the resuming requires a fixed amount of energy just to keep the RAM alive after going to hibernating period. This idle state is used mainly due to two reasons. The first one is, when no information is available for reception and transmission. In that case, saving and accumulating energy is done by this built-in standby option. Secondly, during transmission, when the threshold is reached and no further bits are supported by the mote for both transmission and reception, in such case, the mote must go to its standby state to avoid the restarting and rebooting.

Quantifying the methods of resuming transmission without more delays is the key point of research likewise. In the Table XII, it is clear that reading from flash memory require 2.19 micro Joule and Writing to and reading from flash require 13.1-mJ. The amount of energy 309-nJ and 6-mJ is enough for the mote to keep them alive for one second time (sufficient time for IOT motes) in Low Power (LPM) mode and in CPU (Not LPM, but No wireless communication) respectively. Hence, restarting or rebooting motes, which will read network status after each restart/reboot, consume more energy and causing delay in sending packets.

These emulated research facilitates the user to avoid delays due to waiting for charging pulses. Hence it is of greater usage and will benefit the research community and the user of intermitted nodes based wireless networking platforms.

FUTURE AND MODIFICATIONS

Such leading edge researches are, as mentioned earlier, of greater value to both researcher community and the end user or network employers. We can extrapolate the research by embedding the ROM internally rather externally connecting it to the transmitter/receptor circuitry. That is actually an advancement with respect to the mote's manufacturing. The research can further be furnished if we compare the transmission schemes and other options concerning these motes that may include number of motes, protocols for transmission, packet stream arguments, communication channel particulars, reserved energy quantity, node mobility etc.

The future work may comprise of the above point but is not limited to it. Hence there is a great research and development area waiting for us to explore in IoT and intermitted nodal connectivity in scarce environments.

TABLE XII. SUMMARY OF NODE SIMULATION IN CONTIKI-3.0

Node Nos.	Total	CPU	LPM	Transmit	Recieve
2-Nodes	63.63855	3.612376	0.185581	35.00768	24.83292
3-Nodes	65.10926	3.651581	0.18545	35.53922	25.73302
4-Nodes	67.55953	3.703427	0.185308	35.28126	28.38953
5-Nodes	68.75132	3.730648	0.185186	35.61051	29.22498
10-Nodes	75.0950221	3.8492823	0.1847886	35.35815	35.7027944
15-Nodes	80.54962	3.959707	0.185071	35.41431	40.99053

REFERENCES

[1] Veen, "BLISP: Enhancing backscatter radio with active radio for computational RFIDs," Master's thesis, TU Delft, 2015.

[2] Y. Yang, L. Wang, D. K. Noh, H. K. Le, and T. F. Abdelzaher, "Enhancing data reliability in solar-powered storage-centric sensor networks". In Proc. 7th Annual Int'l Conference on Mobile Systems, Applications, and Services (MobiSys-09), pages 333-346, ACM, 2009.

[3] P. D. Mitcheson et al., "Energy Harvesting From Human and Machine Motion for Wireless Electronic Devices," Proc. IEEE, vol. 96, no. 9, pp.1457-1486, Sept. 2008.

[4] M. R. Mhetre et al., "Micro energy harvesting for biomedical applications: A review," Proc. ICECT 2011, vol. 3, pp. 1-5, 8-10 April 2011.

[5] B. Ransford et al., "Mementos: System Support for Long-Running Computation on RFID-Scale Devices," ASPLOS11, Newport Beach, CA, USA, Mar. 5-11, 2011.

[6] P. A. Bernstein et al., "Concurrency Control and Recovery in Database Systems," Addison-Wesley Longman Publishing, Boston, USA 1987.

[7] Rose Yu, Thomas Whetteyne "Reliable, Low Power Wireless sensor networks for Internet of Things: Making Wireless Sensor as Accessible as Web Server".

[8] C. E. Perkins, "Ad Hoc Networking," Addison-Wesley, 2001.

[9] [9]V. Rajendran, K. Obraczka, and J. J. Garacia-Luna-Aceves, "Energy-Efficient Collision-Free Medium Access Control for Wireless Sensor Networks," Proceedings of the 1st ACM International Conference on Embedded Networked Sensor Systems, 2003, pp. 181-192.

[10]]L. F. W. Hoesel and P. J. M. Havinga, "A Lightweight Medium Access Protocol for Wireless Sensor Networks," Proceedings of the 1st International Conference on Networked Sensing Systems, 2004, pp. 205-208.

[11] T. Hatauchi, Y.Fukuyama, M. Ishii, and T. Shikura, "A Power Efficient Access Method by Polling for Wireless Mesh Network," Transactions of IEEJ, Vol. C-128, No. 12, 2008, pp. 1761-1766.

[12] R. Jurdak, P. Baldi, and C. V. Lopes, "Adaptive Low Power Listening for Wireless Sensor Networks," IEEE Transaction on Mobile Computing, Vol. 6, No. 8, 2007, pp. 988-1004.

[13] Anuj Sehgal, "Using the Contiki Cooja Simulator".

[14] Texas Instrument Inc CC2420 Datasheet. Available on: http://www.ti.com/

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