Energy Analysis of Wireless Sensor Network for Collision Detection on Guardrails

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***Abstract*—Nowadays Wireless Sensor Networks (WSNs) are key enabling technologies in a wide range of applications. This is due to the new technological developments in microelectronics, communication and network. For example, the application of WSN in roads and highways is getting popular due to the low cost implementation and easy installation. This paper attempts to provide a guideline to design an energy efficient WSN dedicated for collision detection in highways. Typically the nodes are powered by batteries and for this reason an accurate energy analysis can expand the overall network lifetime. A Markov Chain model of the developed algorithm for a node is provided in order to investigate energy consumption based on the steady state probabilities. Finally an experimental evaluation is carried out to examine the accuracy of the mathematical investigation.**

Keywords—Wireless Sensor Networks, Energy Analysis, Collision Detection

I. Introduction

WSN [1] has been employed in transportation system especially for safety in highways. For instance, in [2, 3] a Wireless Active Guardrail System (WAGS) has been proposed in order to detect a collision between vehicle and guardrail and enabling early warning of other drivers. In [4] a novel safety warning system based on sensor networks has been presented. In [5], a collision detection system based on accelerometer sensors has been demonstrated. A prototype of the sensor nodes for collision detection has been shown in [6]. An experimental analysis of the WSN for highway and traffic applications based on TinyOS Mica board has been presented in [7]. However, in all the mentioned work, there is a lack of mathematical analysis of the collisions. This motivated the authors to propose a mathematical modelling approach to analyze the materials which is used in the guardrails in order to provide an accurate detection system [8]. In this paper, an experimental analysis of the energy consumption regarding the real implementation of the proposed system in [8] is presented. For this purpose, an energy consumption model is proposed and simulated in order to show the efficiency of the designed network.

II. System Architecture

Fig. 1 presents the proposed system architecture for collision detection. When a collision occurred, the measured acceleration data transmitted to the AP for further processing. The RSWSN is based on Service Oriented Architecture (SOA) providing services to the operators via web browsers, mobile and desktop applications [8].

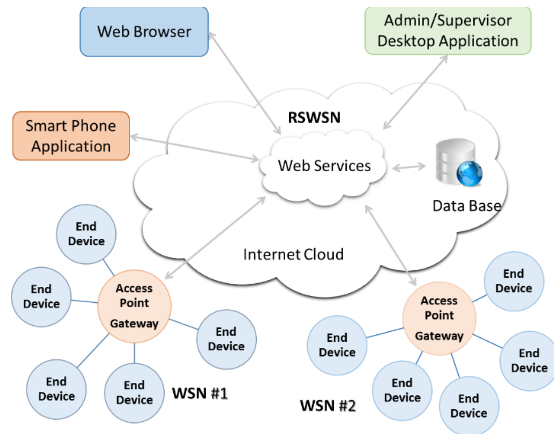

Fig 1. Proposed System Architecture for Collision Detection

III. System Formulation

Fig. 2 presents the state machine diagram of the algorithm implemented in End Device (ED) node.

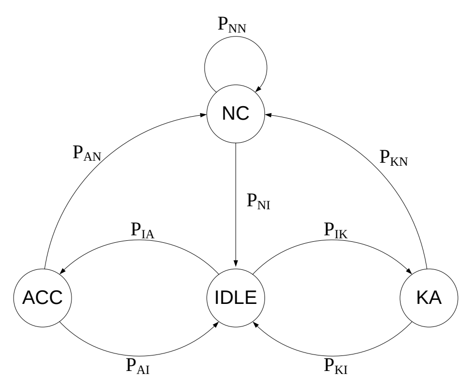

Fig. 2 ED Sate Machine Diagram and Corresponding Probabilities

Based on the transition probabilities, the transition matrix can be calculated. Fig. 3 presents the current consumption of the Keep Alive (KA) state. The KA messages are sent periodically with the period of T. Given t_k, I_{min} , I_{max} and SC, the period of KA message can be computed using equation 2.

$$P = \begin{bmatrix} P_{NN} & P_{NI} & 0 & 0 \\ 0 & 0 & P_{IK} & P_{IA} \\ P_{KN} & P_{KI} & 0 & 0 \\ P_{AN} & P_{AI} & 0 & 0 \end{bmatrix} \quad (1)$$

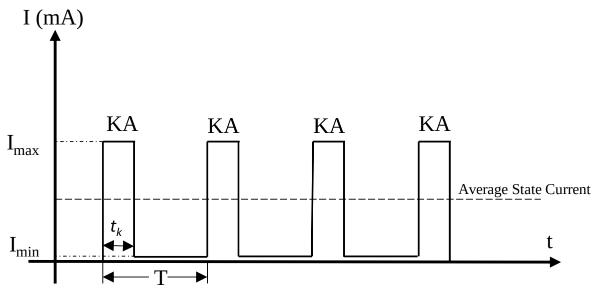

Fig. 3. Current Consumption of KA State

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$$SC = \frac{1}{T}\left[\int_{0}^{t_k} I_{max}\,dt + \int_{t_k}^{T} I_{min}\,dt\right]$$
$$T = \frac{t_k[I_{max}-I_{min}]}{SC-I_{min}} \quad (2)$$

IV. Experimental Evaluation

Fig. 4, demonstrates the simulation of KA period for different battery capacities and time. This graph will help the user to select the best KA period based on the battery capacity or given a KA period, the maximum time for a battery can be determined.

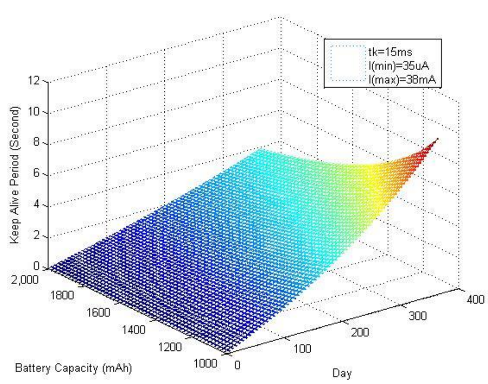

Fig. 4 KA period versus battery capacity and time (day)

V. Conclusion

In this paper, an energy analysis of WSN for collision detection on guardrails has been presented. The collision detection architecture has been proposed previously by the authors and for this reason a careful consideration of the node's energy consumption was required in order to develop an energy-efficient model. For this reason, the Markov Chain model of the designed algorithm for the ED has been demonstrated to observe the energy consumption of each state (Table I and Table II).

Acknowledgment

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TABLE I. Test Results

Description	Value
KA Period (T)	200ms
Calculated Battery Life Time	434.89 hours
Measured Battery Life Time	432 hours
Last Voltage Reading	2.12v
Number of Messages Exchanged	7 776 000

TABLE II. Time of Each State

Description	Value
Network Connection	22.73 hour
Idle	204.63 hour
Keep Alive	200.53 hour
Accelerometer	4.09 hour

References

[1] Akyildiz, IF.; Weilian Su; Sankarasubramaniam, Y.; Cayirci, E., "A survey on sensor networks," Communications Magazine, IEEE , vol.40, no.8, pp.102,114, Aug 2002

[2] P. Daponte, L. De Vito, F. Picariello, S. Rapuano, and I. Tudosa, "Wireless sensor network for traffic safety," in Environmental Energy and Structural Monitoring Systems (EESMS), 2012 IEEE Workshop on, 2012, pp. 42–49.

[3] L. De Vito, V. Cocca, M. Riccio, and I. Tudosa, "Wireless active guardrail system for environmental measurements," in Environmental Energy and Structural Monitoring Systems (EESMS), 2012 IEEE Workshop on, 2012, pp. 50–57.

[4] Kai Xing; Ding, M.; Xiuzhen Cheng; Rotenstreich, S., "Safety warning based on highway sensor networks," Wireless Communications and Networking Conference, 2005 IEEE , vol.4, no., pp.2355,2361 Vol. 4, 13-17 March 2005.

[5] W. Jiao, X. Wang, and L. Zhao, "Monitoring system of car-guardrail accident based on wireless sensor networks," in ITS Telecommunications, 2008. ITST 2008. 8th International Conference on, 2008, pp. 146–149.

[6] S. srl. (2013) Red-wine: Roadside events detection in a wireless network. [Online]. Available: http://www.sistrasrl.it/en/products/traffic.

[7] T.T.Hsieh, "Using sensor networks for highway and traffic applications", IEEE Potentials, vol.23, No.2, April-May 2004, pp.13-16.

[8] J. Miranda, T. Gomes, R. Abrishambaf, F. Loureiro, J. Mendes, J. Cabral and J. L. Monteiro, "A Wireless Sensor Network for Collision Detection on Guardrails", 23th International Symposium on Industrial Electronics, pp. 1426-1431, Turkey, June 2014.