

Energy Management and Modelling in Wireless Sensor Networks- A Review

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ABSTRACT: Wireless Sensor Networks (WSN) have recently been the focus of a significant amount of attention and effort of the research community, and one of the major paradigms to be focused is limited node power/energy. Energy constraint is the major issue in wireless sensor networks as battery recharging is not possible for nodes deployed over vast area and as soon as the battery loses its power the node is dead and will no longer transmit data in the network. Therefore, energy conservation is the only solution available for increasing the life of nodes and thus of the complete network. Before energy optimization we should be able to properly calculate the energy consumption. Energy modeling of a system estimates the energy consumption through various processes. We can model a system and then simulate to predict the energy requirements. This paper presents a review of various techniques for modeling and how Petri Net is a viable and efficient tool for analysis of energy consumption in a system.

KEYWORDS: WSN; energy; modeling; Petri Net.

I. INTRODUCTION

A. Wireless sensor network:

A wireless sensor network (WSN) is a network of spatially distributed nodes having autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure etc. and to cooperatively pass their data through the network to a main location known as base station. The more modern networks are bi-directional, also enabling control of sensor activity.

The WSN is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery.

WSN are quite different from general wireless networks due to different constraints and highly application specific nature, consequently WSN's pose different research challenges, considering the basic differences with wireless communication systems many issues have been identified and investigated. Major issues affecting the design and performance of WSN are: -

- Energy
- Deployment strategy
- Localization
- Routing
- Coverage efficiency
- Efficient Medium Access Control(MAC)
- Quality of Service(QOS) implementation

Sensor nodes have limited power supply and recharging of power is impractical considering large number of nodes and environment constraints in which they deployed. Therefore, energy consumption and evaluation is an important metric to be considered.

B. PETRI NET

A Petri Net (also known as a place/transition net or P/T net) consists of places which represent conditions and transitions which represent events, and arcs. Arcs run from a place to a transition or vice versa. Arcs never run from

place to place or transition to transition. The places from which an arc runs to a transition are called the input places; the places to which arcs run from a transition are called the output places.

In the Petri Net graph, a place is denoted by a circle, a transition by a box or a bar and an arc by a directed line. A Petri Net is a PT-Net with tokens assigned to its places denoted by black dots, and the token distribution over its places is done initially by a marking function denoted by M_0 . A token is interpreted as a command given to a condition (place) for firing an event (transition). An event or transition can fire, when it's all input conditions or places may have sufficient number of tokens. A transition consumes the tokens from input places equal in number to its associated weights sum of its input arcs and puts the token to the output places equal in number to its associated weights sum of its output arcs. So tokens initially in places should be greater or equal to its associated output arcs for firing the corresponding output transitions.

See Fig. 1.

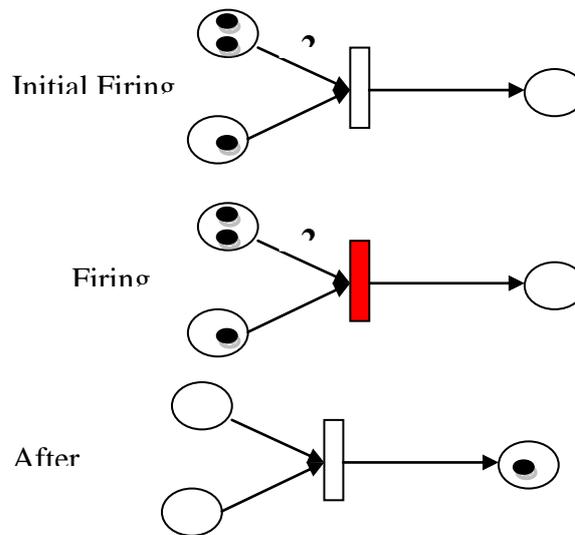


Fig. 1 Petri Net

A Petri Net (also known as a place/transition net or P/T net) is one of several mathematical modeling languages for the description of distributed systems. A Petri net is a directed bipartite graph in which the nodes represent transitions (i.e. events that may occur, signified by bars) and places (i.e. conditions, signified by circles). The directed arcs describe which places are pre- and/or post-conditions for which transitions (signified by arrows). Some sources state that Petri nets were invented in August 1939 by Carl Adam Petri- at the age of 13 — for the purpose of describing chemical processes.

A Petri net consists of places, transitions, and arcs. Arcs run from a place to a transition or vice versa, never between places or between transitions. The places from which an arc runs to a transition are called the input places of the transition; the places to which arcs run from a transition are called the output places of the transition.

Graphically, places in a Petri net may contain a discrete number of marks called tokens. In an abstract sense relating to a Petri net diagram, a transition of a Petri net may fire if it is enabled, i.e. there are sufficient tokens in all of its input places; when the transition fires, it consumes the required input tokens, and creates tokens in its output places. A firing is atomic, i.e., a single non-interruptible step.

Unless an execution policy is defined, the execution of Petri nets is nondeterministic: when multiple transitions are enabled at the same time, any one of them may fire, since firing is nondeterministic, and multiple tokens may be present anywhere in the net (even in the same place), Petri nets are well suited for modeling the concurrent behavior of distributed systems.

Definition 1. A net is a triple $N = (P, T, F)$ where: P and T are disjoint finite sets of places and transitions, respectively. $F \subseteq (P \times T) \cup (T \times P)$ is a set of arcs (or flow relations).

Definition 2. A Petri net is a net of the form $PN = (N, M, W)$, which extends the elementary net so that: $N = (P, T, F)$ is a net. $M: P \rightarrow Z$ is a place multiset, where Z is a countable set.

M extends the concept of configuration and is commonly described with reference to Petri net diagrams as a marking. W: $F \rightarrow Z$ is an arc multiset, so that the count (or weight) for each arc is a measure of the arc multiplicity.

II. REVIEW LITERATURE

Energy minimization is a serious issue in wireless sensor networks to extend the lifetime and minimize costs. However, in order to gain an accurate understanding of issues regarding power minimization, modeling techniques capable of accurately predicting energy consumption are needed. Energy consumption is the core issue in wireless sensor networks (WSN). To generate a node energy model that can accurately reveal the energy consumption of sensor nodes is an extremely important part of protocol development, system design and performance evaluation in WSNs.

An overall model which gave a feasible formulation to express the overall energy consumption of a generic wireless sensor network application in terms of its energy constituents was proposed by Najmeh Kamyabpour et. al [1]. In 2010, A. Courtay et. al. [2] suggested a global power consumption model dedicated to Wireless Sensor Network nodes. In 2011 John Khalil Jacob et. al. [3] studied the distributed nature of WSNs and the interaction between software and hardware components which makes it difficult to correctly design and develop WSN systems. One solution to the WSN design challenges is system modeling. A survey of 9 WSN modeling techniques to differentiate how each technique models different parts of the system such as sensor behavior, sensor data and hardware was done.

In, 2010 SHI Zhang-song et. al. [4], recommended a generalized stochastic Petri net (GSPN) based model to predict the energy consumption of a WSN with the sleep mechanism for constructing the energy map which provided the theoretical basis and numerical foundation for making efficient use of energy. Ali Shareef et. al. 2008, 2010, 2012[5, 6, 7] proved that Petri nets are a viable option of modeling a processor. He proposed a detailed probabilistic model based on Petri nets to evaluate the energy consumption of a wireless sensor node and showed that the Petri nets accuracy surpasses a Markov model utilizing supplementary variables to account for constant delays

Dan Lozneau et. al., [8] implemented a global energy model, generic and portable which gave mathematical approach for each part of the wireless sensor node, adaptable to any sensor node that will be or has been deployed. In 2012 Samuel Kounev et. al. [9], suggested Queuing Petri nets as a powerful formalism that can be exploited for modeling distributed systems and evaluating their performance and scalability. By combining the modeling power and expressiveness of queuing networks and stochastic Petri nets, queuing Petri nets can provide a number of advantages. In 2013 Reza Rasouli et. Al. [10], recommended an analytical model for evaluating energy consumption in term of data transmission, reception and aggregation in cluster based WSNs architecture using M/M/1 queuing model. In 2014J.Li et. al. [11], presented a “state-event transition” formal description for WSN nodes and proposed an event-driven QPN-based modeling technique to simulate the energy behaviour of nodes. Besides, the framework architecture of a dedicated energy evaluation platform had been introduced, which can be used to simulate the energy consumption of WSN nodes and to evaluate the system lifetime of WSN.

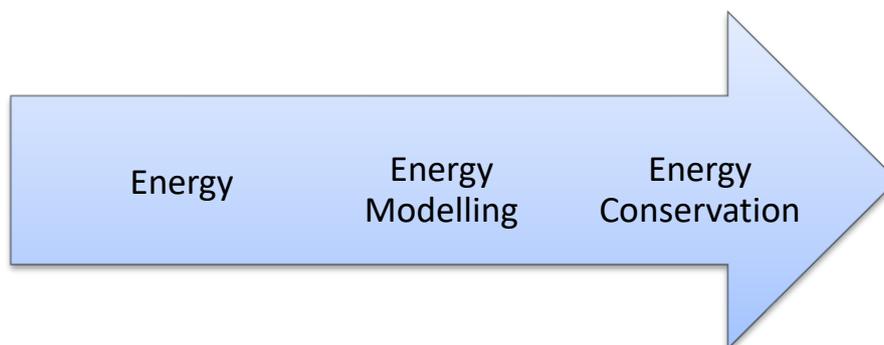


Fig. 2 Significance of Energy Modeling

III. CONCLUSION

For energy conservation and optimization in any network or system the first basic requirement is to model the energy in a proper and efficient manner. A system can be modeled for energy conservation in parts and even a part like sensor node can further be modeled in parts i.e. processor, controller, transceiver, memory, each one individually. Petri net model when compared with Markov model and is proved to be better. Modified Petri net like queuing petri nets or colored petri nets are also efficient for energy modeling of a wireless sensor network.

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