Model based optimisation of EBS-MAC

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ABSTRACT

Decentralised, energy-efficient synchronisation of duty-cycles is a difficult task in Wireless Sensor Networks (WSNs). Popular protocols for this task are inspired by the synchronisation mechanism of fireflies. One such protocol - the emergent broadcast slot (EBS) scheme - achieves high synchronisation levels at low energy cost. However, its performance heavily depends on its configuration. To understand the impact of the protocol parameters better, we analyse a MAC-level implementation of EBS using Castalia, a low-level WSN simulation framework. Moreover, we show work in progress on a scalable GSMP model of EBS.

Categories and Subject Descriptors

C.4 [**Performance of systems**]: Modeling techniques, Performance attributes

General Terms

EBS, GSMP modelling, WSN modelling, Spatial modelling

1. INTRODUCTION

In many duty-cycled WSN applications, nodes need to communicate information with their 1-hop neighbours. This requires neighbouring nodes to have synchronised awake periods during which their radio is turned on. Due to channel interference and a lack of precise clocks in WSN nodes, however, it is hard to achieve such neighbourhood synchronicity. A feasible decentralised solution for this problem is based on the synchronisation behaviour of fireflies [3], which led to the development of EBS [4]. While EBS has the potential to achieve high throughput at low energy cost, its performance is sensitive to its parameter setup. To help end-users optimally configure EBS for their application, we develop and analyse a low-level Castalia [1] implementation of the synchronisation scheme at MAC-level (EBS-MAC). Additionally we present our progress on the creation of a high-level Generalised Semi-Markov Process (GSMP) model of EBS.

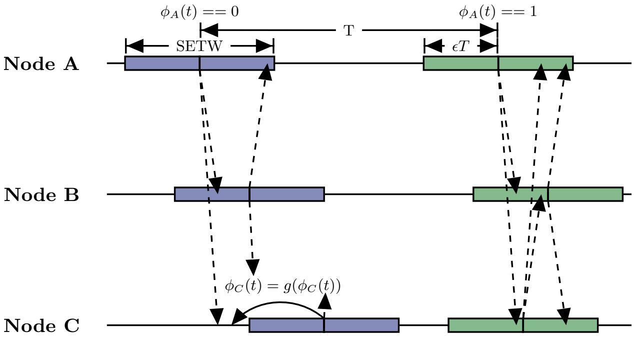

Figure 1: WSN with 3 nodes running EBS-MAC (cf. [4]). Unsynchronised SETW (left), synchronised SETW (right).

2. EBS-MAC

The following section describes EBS as presented in [4]. In EBS nodes are either synchronised or unsynchronised. When synchronised, a node is asleep outside its Synchronisation Error Tolerance Window (SETW), otherwise it remains awake and listens for synchronisation beacons. The length of the SETW is $2\epsilon T$, where T is the duration of the phase and ϵ is a constant. Nodes always send synchronisation messages midway through their SET window. Moreover, a node is considered synchronised if $s/n > s_{Th}$, i.e. when the number of beacons received during the last SETW divided by the number its neighbours is larger than the synchronisation threshold. If $s/n \leq s_{Th}$ a node is unsynchronised. An unsynchronised node that receives a beacon outside its SETW and moves its window forward using the phase update function $g(\cdot)$. Figure 1 illustrates this behaviour for 3 nodes. Initially all nodes are unsynchronised. When A sends its broadcast, B receives it within its SET window and does nothing. Node C, however, is outside its SETW at the time of A's broadcast and thus advances its phase according to $g(\phi_C(t))$. Once node C has moved its phase forward, all nodes receive each others' broadcasts within their SETW. Hence all nodes are now synchronised and their radios remain switched off between subsequent SETWs. In an ideal scenario the window length is $s * time\ to\ send\ a\ msg$, but due to interference and clock drift this is practically impossible. Instead, our challenge is to find optimal $g(\cdot)$, ϵ, s_{Th} for a given topology and phase duration T to maximise broadcast synchronicity and throughput while minimising the energy consumption. Additionally we need to ensure that no node

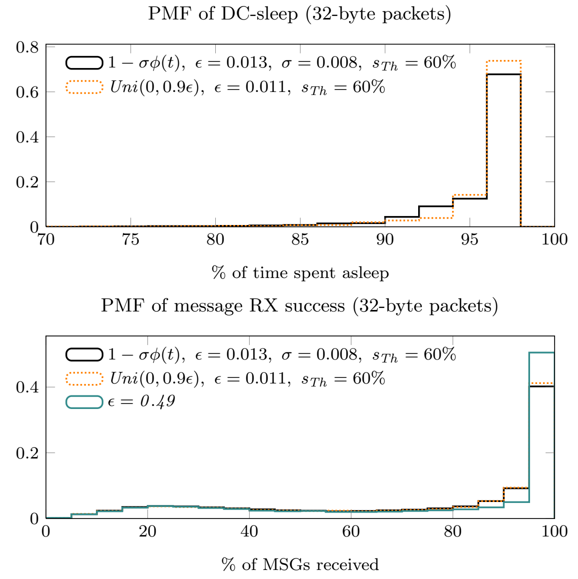

Figure 2: Comparison of average node duty-cycle and throughput probability distribution for different $g(\cdot)$. The results were obtained from 200 Castalia simulation runs with 25 nodes, $T = 30$, avg. $s \approx 6.5$.

continually realigns its SETW with different neighbours.

3. PRELIMINARY RESULTS

Initial simulation results indicated that the choice of $g(\cdot)$ influences occurrence of collisions in SET windows. In a rare worst case scenario when initial phases of the nodes are closely aligned, the original choice $g_\sigma(\cdot) = 1 - \sigma\phi(t)$ [4] can cause nodes to fire broadcast messages simultaneously, which leads to packet collisions. To reduce the risk of packet collisions in SET windows we replaced the original deterministic $g_\sigma(\cdot)$ with a non-deterministic uniformly distributed update function $g_u(\cdot) = Uni(0, 0.9\epsilon)$. Figure 2 compares the configurations with the lowest duty-cycle for these two update functions in a 25 node square grid topology. The parameters were estimated using simulation based parameter sweeping in Castalia. First results indicate that $g_u(\cdot)$ achieves slightly better synchronicity than $g_\sigma(\cdot)$. In addition to this, the non-deterministic $g_u(\cdot)$ function can be optimised faster as it has fewer parameters than $g_\sigma(\cdot)$. The comparison with a nearly fully duty-cycled configuration of EBS ($\epsilon = 0.49$) in the throughput distribution diagram indicates that these two optimised versions of EBS achieve low-level duty-cycle without significant loss in throughput.

4. AN ABSTRACT EBS-MAC MODEL

The motivation for developing a GSMP model of EBS-MAC is to create a formal, scalable WSN model of the protocol. While Castalia provides a realistic simulation environment for WSNs, the resulting simulations become computationally expensive for large WSNs. By developing realistic, but simpler models for WSN protocols we hope to mitigate this effect in the future. Figure 3 shows our current GSMP model for the EBS-MAC protocol described in Section 2. A node's state is affected by internal and message induced transitions. Both transition types are either conditional or delayed. As a node enters state *sl* the transition labelled $[s/n > s_{Th}]$ is triggered immediately if the percentage of neighbours it is synchronised with falls below the synchronisation threshold. State sojourn periods for delayed transitions can be deterministic or non-deterministic. Message induced transitions occur when a node receives a message from a neighbouring node and are affected by channel noise and radio interference. Our aim is to extend this GSMP model to capture a network of nodes running EBS-MAC as well as the radio channel dynamics.

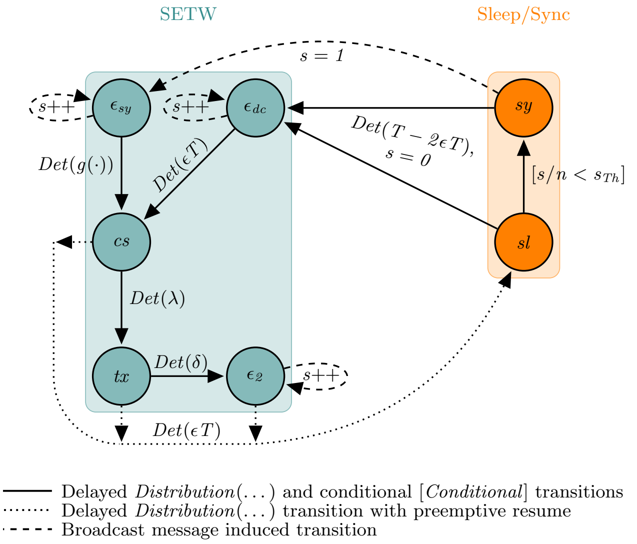

Figure 3: An abstract GSMP model of a WSN node running EBS.

5. CONCLUSIONS AND FUTURE WORK

Although we still need to validate our simulation study empirically, our research on EBS-MAC illustrates how stochastic models can assist engineers in the process of optimising WSN protocols. However, for large networks, discrete event simulation based parameter sweeping is computationally expensive. To overcome this challenge we intend to research GSMP modelling techniques for realistic WSNs as well as scalable mean-field evaluation techniques for GSMPs [2].

6. REFERENCES

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