Competition: Is Concurrent Transmission Flooding a Good Idea for Random Traffic?

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Abstract

Concurrent transmission flooding (CTF), despite its high efficiency, has been considered to be only suitable for periodic traffic models. In this competition, we show that, with a sophisticated scheduling mechanism, CTF could become a reliable and efficient primitive for various traffic demands. Specifically, we demonstrate Choco, a CTF-based communication protocol that energy-efficiently supports burst and random traffic demands with 100 % end-to-end reliability. The scheduling mechanism of Choco dynamically adapts slot assignment according to packet losses and traffic loads, and ensures 100 % end-to-end reliability. Moreover, the mechanism instructs nodes to enter a deep sleep mode when there are no traffic to achieve efficiency even in light random traffic. Experiments that emulate the competition are conducted to prove the robustness of Choco. The results show that Choco consistently achieves 100 % reliability, while ORPL, the state-of-the-art routing-based protocol, suffers from 42 % of packet error rate in interfered environment.

1 Introduction

Versatility, i.e., the capability to efficiently support various traffic demands, has become one of the most important directions to design communication protocols for wireless sensor networks. While the concurrent transmission flooding (CTF) based protocols [1] enjoy the merits of simplicity, robustness and high efficiency, these protocols are often believed to be only suitable for periodic traffic [2].

In this competition, we demonstrate Choco [3], a CTF-based communication protocol which provides lightweight 100 % end-to-end reliability and high efficiency in not only periodic but also random traffic. As described in [3], we design Choco on the insight that ACKs between ends can be delivered with little overhead using CTF. Choco is a slotted communication protocol like other CTF-based protocol (e.g., LWB [1]), where the sink node works as a master that polls and coordinates all the other nodes by sending scheduling packets over on-demand intervals.

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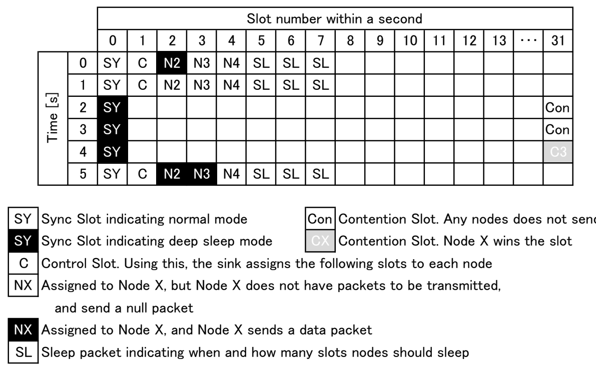
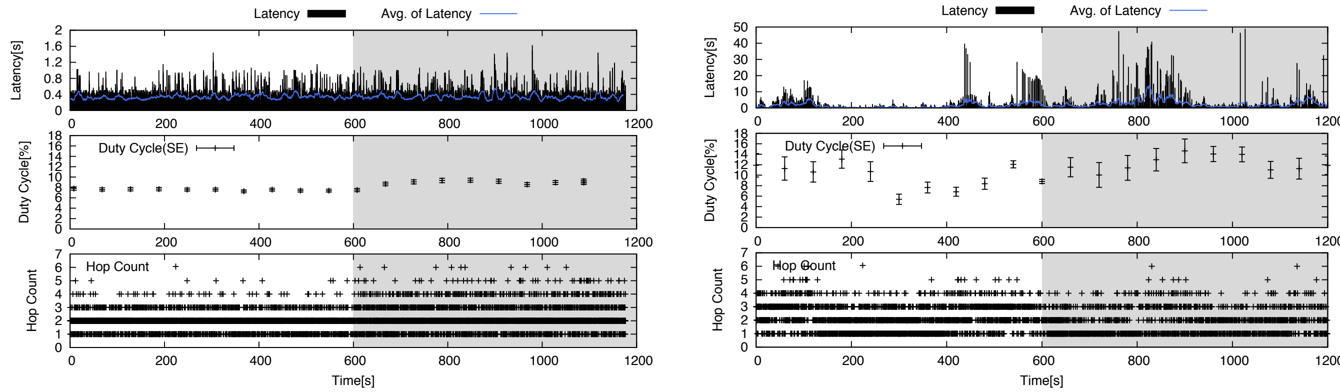


Figure 1: Example of deep sleep mode in Choco

Choco guarantees 100 % end-to-end reliability by the following mechanism: *1*) the nodes retain all the packets that might be retransmitted with end-to-end acknowledgements; *2*) the sink node continues to reschedule retransmissions for the lost packets until a successful reception or a node failure detection; *3*) while the packet travels through the network, the packet is replicated and forwarded through multiple paths. In interfered environment, while some of the paths might be blocked, there could still be some surviving paths which successfully deliver the packet to the sink node.

Choco can energy-efficiently convey random light traffics. In view of the fact that continuously polling many nodes could lead to significant overhead in light-traffic model, a deep sleep (DS) scheme is adopted in Choco to enhance the energy efficiency in light traffic scenario while maintaining short latency. Figure 1 illustrates the operation of the DS mode. In this example, we assume that sync slots are deployed every second and there are 32 slots per second. In the normal mode, the sink node first allocates a slot to each node for packet transmission by sending a control packet. When all buffered data packets are received, the sink node instructs all of the nodes to enter sleep mode by sending sleep packets which include a wake-up time.

When there are no data packets to be received during one polling for every node, the sink node instructs the nodes to enter the DS mode by raising the DS flag carried in the sync packet. In DS mode, sensor nodes only wake up in the periodic sync slots to maintain timing synchronization with the



(a) Choco (b) ORPL

Figure 2: Measured result of the 2nd experiment: per-packet latency, hop count, and average latency over time

sink node. Right before each sync slot, a special contention slot is allocated. Nodes which have data to be transmitted first send a notification packet in the next contention slot. Upon the successful reception of notification, the sink node wakes up all the nodes in the next sync slot. In our example, node 3 transmits a notification packet in the contention slot at the end of the 4 s. In the beginning of 5 s, the sink node wakes every nodes up by sending a sync packet whose DS flag is pulled down.

2 Evaluation Methodology

To evaluate the performance of Choco, experiments that emulate the competition scenario are conducted using 22 TelosB motes. In the experiments, five sensor nodes generate and transmit 10-byte dummy packets at random inter-packet intervals (IPIs). The IPIs are uniformly distributed random numbers, whose average is set to be 1 s and 60 s to test both heavy and light traffic models, respectively. Between the sensor nodes and the sink node, 15 nodes are tightly deployed as relay nodes for data forwarding. In addition, one node is programmed as an interference node which generates interference using JamLab. The output power of each node is set to be the minimum value, and the sensor nodes and the sink node are properly separated so that the one-hop links between the sink and the sensor nodes are not reliable. The slot time of Choco is fixed at 31.25 ms, and the polling interval is set to be 0.5 s for Choco. The CCA check rate of ORPL is set to be 8 Hz. We compare the packer error rate (PER), latency, duty cycle and hop count of Choco and ORPL [2] under both interfered and interference-free scenarios. All nodes are directly connected to a logger PC. The latency is measured by calculating the time difference between the packet transmission and reception.

3 Result

Table 1 shows the averaged PER, duty cycle, latency, and hop count for both Choco and ORPL in the interfered and interference-free scenarios. First, from the reliability point of view, we notice that ORPL suffers from noticeable PER loss in the heavy traffic scenario. Particularly, its PER significantly deteriorates to 41.8 % in the interfered environment. On the other hand, Choco always achieves 0 % PER even in the interfered and heavy-traffic scenario. Second, due to the robustness of the CTF and polling mechanism, Choco

Table 1: Comparisons between Choco and ORPL. Every value is averaged performance over all nodes.

Protocol		Choco		ORPL	
Interference		OFF	ON	OFF	ON
Avg. IPI=1 s	PER	0 %	0 %	8.60 %	41.8 %
	Latency	0.326 s	0.336 s	1.22 s	2.55 s
	Duty Cycle	7.59 %	8.79 %	9.85 %	12.5 %
	Hop Count	2.05	2.24	2.27	1.90
Avg. IPI=60 s	PER	0 %	0 %	0 %	0.57 %
	Latency	0.318 s	0.304 s	0.339 s	0.345 s
	Duty Cycle	3.45 %	3.52 %	1.72 %	4.25 %
	Hop Count	1.75	2.32	2.60	2.30

stably provides approximately 0.3 s of latency no matter in which scenarios. However, the latency of ORPL could be affected greatly by the traffic model and interference. Moreover, the latency performance of Choco suppress ORPL in all scenarios. Third, when it comes to energy efficiency, Choco also outperforms ORPL in most of the scenario. Especially in light traffic mode (averaged IPI = 60s) where the polling mechanism and synchronization are expected to bring huge overhead, Choco still provide a decently low duty cycle with the help of DS mode. Finally, we note that while the hop counts of Choco increase in interfered environment, those of ORPL decrease instead. The reason behind is that, unlike Choco which always utilizes every available paths, the packet propagation path of ORPL is limited. Therefore, in the interfered environment, only near nodes can enjoy reliable link, and packets from far sensor nodes which need to be forwarded by many hops are usually not able to survive. This leads to an underestimation of averaged hop count.

Figure 2 shows the per measure latency, duty cycle, and hop count with averaged IPI set to 1 s. The shaded parts represent the time interval when interference nodes are transmitting. These figures clearly demonstrate the stability of Choco. Particularly, while the maximum latency of Choco is always lower than 2 s, the latency of ORPL various dramatically (up to 50s) in the interfered environment.

4 References

[1] F. Ferrari et al. Low-power wireless bus. *In Proc. of SenSys*, 2012.

[2] S. Duquennoy et al. Let the tree bloom: Scalable opportunistic routing with orpl. *In Proc. of SenSys*, 2013.

[3] Y. Katsumata et al. Demo abstract: Choco - a versatile communication protocol in wireless sensor networks. *In Proc. of SenSys*, 2015.