Competition: Robust Flooding using Back-to-Back Synchronous Transmissions with Channel-Hopping

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Abstract

We present a new protocol that is based on consecutive, synchronous transmissions. By aligning transmissions based on timeouts, the protocol becomes more resilient to interference. We propose two methods to mitigate the effect of less accurate temporal packet alignment, namely time synchronization and random transmit powers.

1 Introduction

The goal of our protocol is to report events that happen at a source node to a sink node within a multi-hop network, under significant interference. At the same time, we strive to minimize the reporting latency, maximize the reliability and consume as little energy as possible.

There are different dimensions a jammer can influence communication: frequency, space, and time. In each of these dimensions, we expect jammers to block either a single channel or multiple channels, spatially distributed or within the entire area, for short times or longer periods.

As shown by [4], synchronous transmissions, as used in Glossy [1], combined with channel-hopping is a promising strategy to achieve fast and reliable multi-hop communication. Glossy periodically floods packets in consecutive rounds. Each flood is divided into several slots and nodes sending in the same slot (*i*) transmit identical packets, and (*ii*) temporally align their packets such that a receiver can successfully decode the packet with high reliability. Time alignment needs to be within $0.5\mu s$ to generate constructive interference [1].

The key to the robustness in Glossy is the inherent redundancy on different levels, which coincide with the possible dimensions of a jammer:

Spatial Redundancy. By flooding the packets within a round, Glossy exploits many possible routes at the same time, thus making it less sensitive to individually blocked communication channels.

Temporal Redundancy. By repeatedly sending the same packet within a round, a higher probability of successful transmission is achieved.

Frequency Redundancy. With channel-hopping, as described in [4], slots within a round are assigned different channels. A locally blocked frequency therefore only affects individual slots.

Although these redundancies provide a solid basis, the Glossy communication pattern with channel-hopping has a distinct disadvantage. To accurately time the transmission of synchronous packets among nodes, nodes rely on receiving a packet in every other slot. If packet reception is unsuccessful, the next slot will not be used for a transmission and is therefore wasted. In the worst case, an entire flood can halt, e.g., when a channel is blocked across the entire network. A possibility to mitigate this effect is to restart a flood at the initiator after no packets have been received for a certain time.

Extending this mechanism further, we propose a protocol that transmits packets solely based on timeouts, i.e., after the first reception, no other receptions are necessary in order to generate the remaining packets of the round.

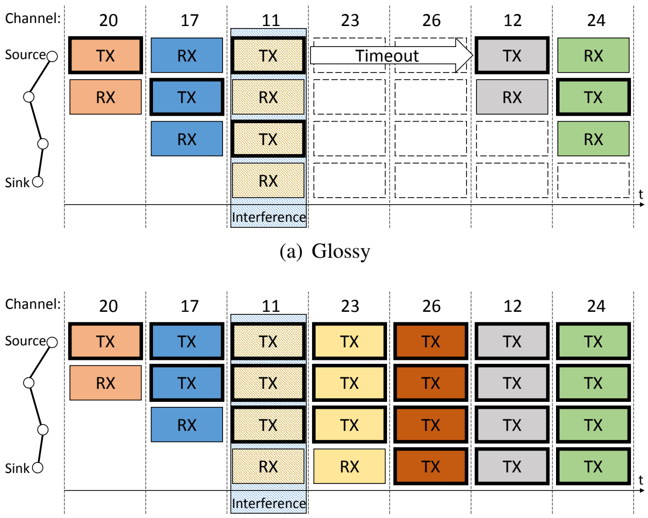
2 Robust Flooding

We illustrate the impact of interference on Glossy with channel-hopping and our new protocol using the example given in Fig. 1. In this example, a jammer is blocking the frequency spectrum that corresponds to channel 11.

In Glossy, all packets in a slot are sent in the same channel [4], and the flood stops after using channel 11 because no node is able to receive this packet. After some timeout, the initiator node (source) restarts the flood. Critically, the position of the blocked channel defines the maximal number of hops information can propagate in the network. In addition, every time a flood stops, precious time and energy is wasted.

Our new protocol uses consecutive, synchronous transmissions. Similar to Glossy, communication is organized in rounds and slots. Once a packet is received, nodes use a local timeout to schedule a transmission in the next slot. In the case of a blocked channel, information is not propagated. However, in the following slot, the flood can continue at the same progress level. In addition, there are no wasted slots during a timeout period.

Our protocol further strengthens two of the redundancies mentioned in Sec. 1. In the spatial domain, due to no inter-



(a) Glossy

(b) Consecutive, synchronous transmissions

Figure 1. Impact of interference on a flood using a) the Glossy scheme and b) consecutive synchronous transmissions.

mediate receive slots, all possible links between nodes are utilized. In a round, within the same time interval as Glossy, our protocol can send each packet more often, therefore increasing the probability of reception.

Implementing such a protocol is challenging, because timeouts need to align packets on neighboring nodes very precisely. With increasing misalignment, constructive interference is not taking place anymore. The capture effect, as exploited in Chaos [2], requires less strict alignments. However, the probability of successful capture decreases, the more transmitters are sending concurrently. In an experiment in [2], the probability of receiving a packet is less than 50 % when more than 3 senders transmit at the same time. Relying on the capture effect only might diminish the benefits of our protocol.

Next, we describe two methods that help to mitigate the problem of temporal misalignments in our protocol.

Time Synchronization. To better synchronize concurrent transmissions, we employ time synchronization based on linear regression, similar to FTSP [3]. Based on packet timestamps in a flood, all nodes compute their local time offset and clock skew to the initiator node. Using this information, packets can be timed more precisely, helping to better align packet transmissions.

Randomized Transmit Power. The capture effect occurs when a radio receiver is processing signals that are received with different signal strengths at the same time. If the difference between the signal powers is large enough, the strongest signal can be decoded with high probability. We can use this fact in our protocol by introducing random transmit powers to artificially increase the diversity in signal strengths.

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3 References

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