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COMMUNICATION PROTOCOL FOR CONSTRUCTIVE INTERFERENCE FLOODING IN WIRELESS SENSOR NETWORKS

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ABSTRACT

Wireless sensor networks (WSNs) are utilized to carry out sensor measurements under different conditions. In case of sparse topology, a multi-hop single path routing is usually used to pass information from a source node to a destination node. A problem with this approach is the loss of connectivity of nodes in the path between source and destination, which may lead to network partitioning. Constructive interference (CI) is used to increase the transmission range of the node and connect disconnected parts of a network to overcome the separation problem. CI- based flooding first presented by Glossy can realize millisecond network flooding latency and sub-microsecond time synchronization accuracy, adapt to topology changes and require no network state information. However, Glossy suffers the scalability problem. The packet reception performances of the forwarded nodes degrade significantly as the size or the density of the network increases. In addition, Glossy produces substantial unnecessary data forwarding, which significantly reduces the network lifetime. In this paper, we propose a multi-hop selective CI-based flooding (MSCIF) approach to improve the CI flooding scalability and reduce energy consumption. The proposed protocol works on a cluster-based network and build a virtual backbone from source to destination, consist of the best dominant nodes to perform the flooding. The dominant nodes are selected based on distances between hops and the residual energy in each node. The mathematical analysis shows that the proposed approach reduces the energy consumption and improves the packet reception ratio (PRR).

Keywords: *Wireless Sensor Networks, Constructive Interference; Cooperative Transmission; Clustering; Selection mechanism*

1. INTRODUCTION

Conventional wireless communication systems consider packet collisions as a problem and try to avoid them by using techniques like channel reservations, carrier sense, or arbitrated medium access (TDMA, polling). The intuition is that concurrent transmissions make packet transmission undecodable and cause irretrievable bit errors at the receiver. However, researchers have found that this view is too conservative. The researchers have proved that the packets can still be decoded successfully at the receiver despite collisions, if the signal of interest power exceeds the sum of interference from colliding packets by a certain threshold, the stronger signal will be received and decoded. This effect, referred to as the capture effect [1], has been validated in many practical studies on different communication systems such as IEEE 802.15.4 [4]– [5] and IEEE 802.11 [2]– [3]

Recently, researchers have explored that it is probable for some or all packets in a collision to survive. There are opportunities to improve the network throughput, increase the overall channel utilization, if we design protocols that select terminals carefully for transmitting simultaneously [6], [7]. The concurrent transmission benefits are not just of theoretical interest but have been verified practically and implemented in application areas such as any-cast [8], [9], rapid network flooding [10]- [14], or neighbor counting [15], especially in wireless sensor networks (WSNs). Protocols exploiting concurrent transmissions have shown potential improvement in the performance of existing wireless communication systems. Their success cannot only be explained with capture effect based on the Signal to Interference and Noise Ratio (SINR). Current studies have proved that, while the relative signal powers of interfering packets play an important role in the reception probability, other factors are of major importance. For example, several experimental studies shown that the relative timing between colliding packets has the most significant influence on the reception performance [3], [16]. Recently, Backcast [9] and Glossy [11] reveal that it is feasible for a common receiver to decode concurrent transmissions of an identical packet with high probability, if multiple transmissions are synchronized accurately. Their works enable concurrent transmissions to interfere constructively.

Constructive interference (CI) is used to increase the transmission range of the node and improve network connectivity. CI- based flooding first presented by Glossy can realize millisecond network flooding latency and sub-microsecond time synchronization accuracy adapt to topology changes and require no network state information. However, Glossy suffers the scalability problem. The packet reception performances of the forwarded nodes degrade significantly as the size or the density of the network increases. In addition, Glossy produces substantial unnecessary data forwarding, which significantly reduces the network lifetime.

Our main contributions in this paper are:

- Analytical study of CI and how it can enhance network connectivity
- Propose MSCIF protocol which exploit CI and improve network performance.
- Mathematical analysis of energy consumption and scalability of the proposed protocol.

1.1 Network Connectivity

Figure 1 illustrates the power addition of transmitting nodes. If the transmitted electromagnetic waves of nodes are of the same amplitude and perfectly synchronized, the amplitude of the received wave is times that of each component wave. Consequently, the channel capacity is increased. For a channel with adaptive white Gaussian noise, the channel capacity is [12].

$$C = W\log_2\left(1+\frac{P_r}{\sigma^2}\right),$$

where W is the bandwidth in Hertz, σ^2 is the adaptive white Gaussian noise dispersion, and P_r is the average power received. When each node transmits its own information independently, Pr is equal to the summation of each transmission power multiplied by their respective attenuation. For identical attenuation a, identical transmission power P_t, and transmitting nodes N, P_r is equal to aNP_t . However, if the signals combine coherently, the average power received can be written as [12]

$$P_r = aN^2 P_t,$$

where P_r increases with the square of the number of transmitting nodes.

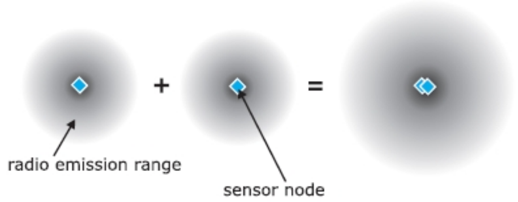

Figure 1: Increasing The Emission Range By Summation Of The Radio Power

1.1.1 RSSI Observations under CI

In telecommunications, received signal strength (RSSI) is widely used to measure the power level of received signals by the antenna. Xiaoyu et al. [17] conducted an experiment to a receiver and observe the RSSI trend of signals under CI with k transmitters and illustrates the results in figure 2. We find in this figure that the RSSI value sampled at receiver side shows an interesting trend with the increase of number of concurrently transmitting senders. The RSSI of 5 transmitting nodes' signal is stronger than the value of a single signal, which means that RSSI enhances with signal superposition. Given the superposed signal CI(k) under CI, let A be the amplitude and τi denote the phase offset with respect to the first signal generated by transmitter i = 1. Consider one IEEE802.15.4 standard based communication system, $RSSI_{CI(k)}$ is equal to [17]

$$RSSI_{CI(k)} = 20\log\left(\sum_{i=1}^{k} A_i\cos(\omega_c\tau_i)\right),$$

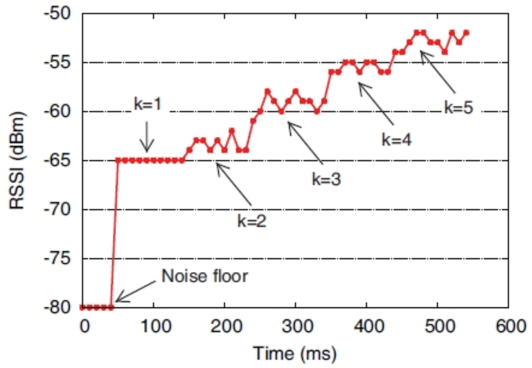

Figure 2: RSSI Values Observed At The Receiver Side When K Senders Simultaneously Transmit Packets With Identical Content To The Receiver [17].

aNP_t

1.2 Constructive Interference

Glossy [11] the pioneer of this new generation of primitives, is considered as the basis for many recent CI approaches. Timing requirements for constructive interference depends on the communication scheme. Glossy first reviewed the IEEE 802.15.4 modulation, and then derive the max temporal displacement among multiple concurrent packet transmissions to be received with high probability. Figure 3 shows a simple CI-based generated signal at a base station (BS).

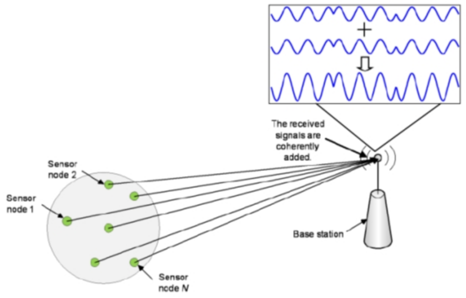

Figure 3: Generating CI From Coherently Added Signals

The IEEE 802.15.4 node is operating in the 2.4 GHz band. The data to be sent is first divided into 4-bit groups each creating a symbol. Each symbol goes through a Direct Sequence Spread Spectrum (DSSS) modulation. Each symbol is modulated with a pseudo-random noise (PN) sequence of 32 chips. The symbol-to-chips mapping is determined in the IEEE 802.15.4 standard [18]. This baseband signal is then modulated to the carrier with Offset-Quadrature Phase Shift Keying (O-QPSK), which is transmitted over the wireless medium. At the receiver, a coherent detection method is used to demodulate the carrier signal. The signal is down-converted into chips, which are then mapped back to the symbols using Maximum Likelihood Estimation (MLE). PN sequence introduce redundancy allows for coping up with errors caused by the channel or soft-decisions at chip-level. This redundancy improves the receiver sensitivity level at the cost of reduced data rate. For CI to occur, the maximum temporal displacement between received signals is 0.5 µs [11], since the chips on quadrature phase (Q-phase) are delayed by the chip time, *Tc* = 0.5 µs from the in-phase (I-phase) carrier. As mentioned in [19], let the O-QPSK signal be represented by,

$$S(t) = I(t)\cos\omega_c t - Q(t)\sin\omega_c t. \qquad (1)$$

Here, I(t) is the I-phase, Q(t) is the Q-phase component, and ωc =pi/2Tc is the radial frequency of half-sine pulse wave. The resulting constructively interfered signal is given by,

$$S_r(t) = \sum_{i=1}^{K} A_i S_i(t-\tau_i) + N_i(t), \qquad (2)$$

where, K is the number of concurrent transmitters, *Ai* is the amplitude and τ_i is the temporal offset of the ith transmitted signals. *Ni(t)* is the noise added to the signal.

1.2.1 Constructive Interference Conditions

Disco [14] derived a theoretical sufficient condition (SC) for concurrent transmissions with IEEE 802.15.4 radio to interfere constructively.

i) Concurrent transmissions with an identical packet should be synchronized at chip level, namely less than *Tc=0.5µs.*

ii) The phase offset of the i^{th} received signals should satisfy:

$$|\tau_i| \le \cos^{-1}\frac{P_i}{P_1}\Big/\omega_c \quad \text{(SC-I);}$$

iii) The ratio of the minimum SNR λ_{min} and the maximum SNR λ_{max} of concurrent transmissions should satisfy:

$$\frac{\lambda min}{\lambda max} \ge \frac{1}{\sum_{i=1}^{N}(\cos\omega_c\tau_i)^2} \quad \text{(SC-II).}$$

2. RELATED WORKS

Constructive interference (CI) is a physical layer phenomenon and was first discovered by Dutta et al. [30]. Then, CI is used in Backcast [31] to solve broadcast storm problem. CI requires that multiple nodes simultaneously transmit the same packet. This behavior is reliable with the characteristics of network flooding. Glossy [11] achieves the synchronization condition ($\Delta \le 0.5\ \mu$s) of CI by capturing interrupts of IEEE 802.15.4 radio. Achieve accurate synchronization with high reliability of CI flooding. However, Glossy produces considerable unneeded packets during the flooding process. This leads to huge unnecessary energy consumption. LWB [19], Chaos [20], and Choco [21] proposed scheduling mechanisms for data dissemination or collection based on Glossy. Their works [19–21] achieve low duty cycle and efficient network flooding. Nevertheless, they do not basically change the transmission mechanism of

Glossy which brings redundant energy consumption. Splash [22] builds up a parallel pipeline by scheduling channel switch between nodes on adjacent layers. Splash can attain higher throughput than Glossy. However, repeated channel switching increases the cumulative synchronization Error which decreases reliability. Meanwhile, channel scheduling increases the energy consumption. Recently, Wang et al. [13] prove that Glossy suffer from a scalability problem. The PRR of Glossy is inversely proportional to the hops of independent paths. The reason is that independent paths increase cumulative synchronization errors. Wang et al. present a SCIF protocol which utilizes grid topology to reduce the number of independent paths. Nonetheless, the grid topology enlarges the path length of CI-based flooding and increases the network latency. CXFS [23] uses the changes of relay count to perform forwarder selection, to some extent, reducing the number of transmitting nodes. CXFS costs significant computational overhead and energy consumption due to the randomness of relay count [24].

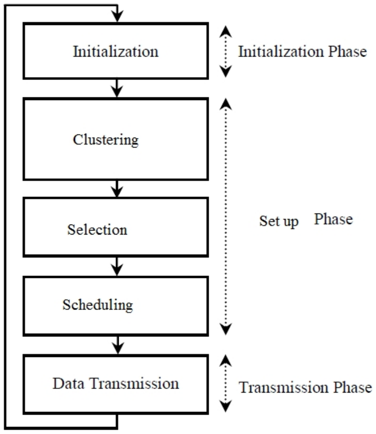

Figure 4: Proposed Protocol Operation

3. MSCIF PROTOCOL

MSCIF is a Multi-hop Selective Constructive Interference protocol. As shown in figure 4, the MSCIF protocol includes three main phases; initialization phase, set up phase and transmission phase. The set up phase consists of clustering phase, selection phase and scheduling phase.

3.1 Initialization phase

A common control code is used during initialization [32]. A non-clustered node listens to the control code until timeout. It then transmits its own ID (using the control code) and replicates the process until it receives a broadcast from a neighbor. CSMA is employed as the channel access in this phase. CSMA is a basic communication facility that enables nodes to arrange themselves in clusters based on the clustering algorithm. User data can only be accepted by the nodes and transmitted in the network when the code assignment is finished, that is, after each cluster has its own code).

3.2 Clustering

The proposed protocol requires an effective clustering algorithm. A cluster is comprised of nodes close to each other. The concentration of the nodes in a cluster simplifies the data exchange inside the cluster. The clustering algorithm should be energy-efficient because of a limited energy supply. The motivation of the algorithm is the clustering algorithm, described in [25]. The algorithm is improved to achieve a better concentrated cluster organization and uses the following assumptions:

- Each node has a unique identification number (ID).
- Messages transmitted by each node must be received without errors in a finite period of time.
- The network topology must not change during the session.

Algorithm:

The clustering procedure involves the following steps:

1. Each node broadcasts its ID to its one-hop neighbors and therefore knows the number of neighbors and their IDs.
2. Each node broadcasts the number of its neighbors to adjacent nodes.
3. Each node forms a table with the IDs and number of neighboring nodes. Each node table is supplemented with information regarding the cluster of every neighboring node.
4. The cluster CID is the ID of the node in the cluster with minimum ID.

Notice that our clustering algorithm has no clusterheads determined, because our communication protocol allows all the selected nodes to transmit directly to the destination, not through clusterheads as in conventional clustering. This will save the network energy and reduce the network latency.

3.3 Selection mechanism

As aforementioned in section 1.2.1, the first condition for CI and the most important one is eliminating the phase offset between the superposed signals to be less than 0.5 µs. This stringent condition requires that the transmitting nodes should be almost at the same distance from the receiver, so that the transmitted signals can arrive at the same time and detected correctly without any loss of data. Based on that, we are selecting cooperating nodes which are within a specific distance from the destination, this eliminate the displacement error through the multi hops and consequently improve the synchronization accuracy and the PRR. Furthermore, when nodes are at the same distance, the received signals will have convergent values of signal strengths, and so we can avoid the occurrence of capture effect. Our selection mechanism works on the clustered network, and selects the nodes based on the residual energy and minimum distance between hops, the algorithm steps are:

1. The base station (BS) broadcasts advertisement message through the network.
2. The neighbor cluster nodes measure their Residual Energy, and send back to BS.
3. If the residual Energy of a node greater than a determined threshold, the node performs the next step, else the node goes to sleep.
4. The neighbor cluster nodes measure the RSSI, calculate their distances from the BS and send back an ACK beacon signal to BS.
5. After receiving the ACK beacons from all nodes, BS calculates their distances from itself. Then average the two calculated distances to have final approximate.
6. Based on these estimates, BS allocates the first selected group identity to those nodes which lies within the minimum calculated distances.
7. The node in the allocated group with the highest remaining energy will repeat the previous process to select the second group nodes.

3.4 Scheduling

To eliminate inter-cluster collision, a general transmitting code is assumed in each cluster [25]. Packet size is supposed to be fixed. To receive the packet, the receiver must tune to the transmitter code. The distance between two nodes in the same cluster is at most two hops.

The MAC layer is implemented within each cluster by using a TDMA model. Time is divided into slots. Slots are grouped into frames. Figure 5 indicates that n nodes are presented in a cluster. A slot is assigned to each node to transmit data information or control. A free slot is reserved in each frame for a new node that will join the cluster. Through the control code, the nodes in the cluster alternate in sending periodic transmissions in the free slot. Their cluster and code information are used to attract migrant nodes or new nodes. A node listens to the channel for a specific period before it makes the decision to join a cluster. The node then uses this free slot to transmit packets temporarily. A single free slot is sufficient because cluster switches are infrequent. The frame is readjusted after each node joins/leaves.

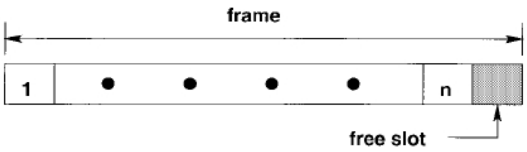

Figure 5: Channel access frame within a cluster [25].

3.5 Data Transmission using Glossy

Glossy [11] is the first flooding protocol exploiting constructive interference of IEEE 802.15.4 symbols for fast flooding and implicit time synchronization. In Glossy, nodes turn on their radios, listen for communications, and immediately relay overheard packets after receiving them. The neighbors of a sender receive a packet at the same time, so they will start relaying the packet also at the same time. This triggers other nodes to receive and relay the packet.

Before the first transmission the initiator sets c = 0. Nodes increment c by 1 before relaying a packet. Consequently, a node can guess from the relay counter how many times a received packet was relayed, as shown in the lower part of figure 6. We define the slot length T_{slot} as the time between the start of packet transmission with relay counter c and the start of the next packet transmission with relay counter c+1. Using timestamps of the radio interrupts, nodes locally estimate T_{slot}. T_{slot} is a network-wide constant, since nodes never change the packet length during a flood. To achieve accurate time synchronization, the initiator embeds its own clock value into the flooding packet, and all nodes who receive from the initiator synchronize their clocks to this reference time.

Figure 5 shows the core of Glossy, characterized by the repetitive sequence of states Wait! Receive! Transmit. The Glossy starts using startGlossy (). Afterwards, a receiver begins the execution in the Wait state. The initiator, instead, starts from state Transmit, and transmits a packet with relay counter c = 0. After this startup phase, the execution is the same for both initiator and receivers, as described in the following.

In the Wait state, a node has its radio turned on and waits for a packet being flooded through the network. When the radio indicates the beginning of a reception, the microcontroller unit (MCU) starts to read the incoming packet. This action corresponds to a transition to the Receive state. If the reception fails, the node returns to the Wait state. Otherwise, if the reception succeeds, the node makes a transition to the Transmit state.

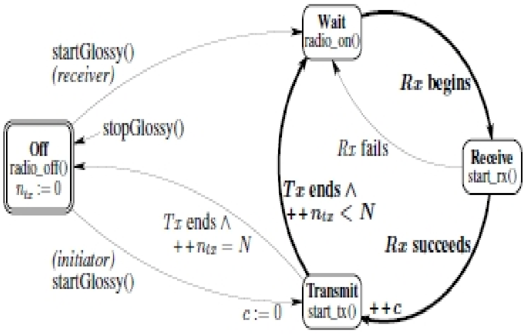

Figure 6: States of Glossy during execution. Transitions in the main state sequence (bold arrows) are triggered by radio events [11].

4. MATHEMATICAL ANALYSIS

4.1 Energy Consumption Model

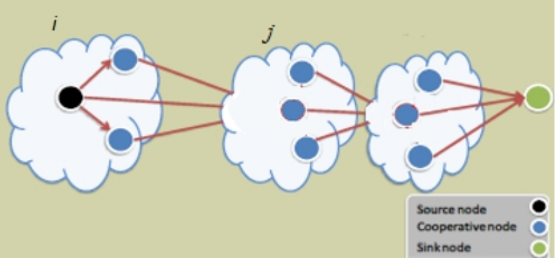

Figure 7: Multi- hop cluster-based cooperative transmission

First we consider energy consumption that employs cooperative communications for data transmission/reception as shown in figure 7. We will calculate the total energy consumption in cluster '*j*'. There are two main components of cluster energy, energy consumption during reception from the neighbors and the energy consumption during data transmission to the next hop.

$$Data\ in\ cluster\ 'j' = \sum_{i=1}^{N} l_i + \{Data\ sensed\ in\ cluster\ j\} \times FF \quad (1)$$

Where '*li*' is sensed data in neighbor '*i*', and *FF* is the fusion factor [27]. Cluster '*j*' has to forward the data of '*N*' number of neighbor clusters in addition to its own data. The load (sensed data) on neighbors can be expressed as

$$l_i = \sum_{v=1}^{n_{l_i}} C_v(i), \qquad i = 1, 2, \ldots, N \qquad (2)$$

If the clustering was conventional (with cluster head), the Energy consumption in cluster j equals [28]:

$$\begin{aligned}
&Energy\ consumption\ in\ cluster\ 'j' = E_{RCV\_coop}\left\{\sum_{i=1}^{N} l_i\right\} \\
&+E_{TRANS\_nodes}\{(Data\ sensed\ in\ cluster\ j)\} \\
&+E_{RCV\_CH}\{Data\ sensed\ in\ cluster\ j\} \\
&+E_{TRANS\_coop}\left\{\sum_{i=1}^{N} l_i + (Data\ sensed\ in\ cluster\ j) \times FF\right\} \\
&+E_{RCV\_OH\_trans\_CCH\_CH}\left\{\sum_{i=1}^{N} l_i\right\} + E_{RCV\_OH\_rcv\_CH\_CCH}\left\{\sum_{i=1}^{N} l_i\right\} \\
&+E_{TRANS\_OH\_trans\_CH\_CCH}\left\{\sum_{i=1}^{N} l_i + (Data\ sensed\ in\ cluster\ j) \times FF\right\} \\
&+E_{TRANS\_OH\_rcv\_CCH\_CH}\left\{\sum_{i=1}^{N} l_i + (Data\ sensed\ in\ cluster\ j) \times FF\right\}
\end{aligned} \qquad (3)$$

where E_{RCV_coop} is the energy consumption for cooperative reception in cluster '*j*' (for each neighbor '*i*', cluster '*j*' has different receive number of nodes, which are determined by that neighbor '*i*'), *E RCV_ CH* is the receive energy consumption of cluster head (CH) for its own cluster data, *E TRANS_ nodes* is sensor nodes transmission energy in cluster. *E TRANS_coop* is cooperative transmission energy, *E RCV _OH _trans _CCH_CH* is received overhead during transmission from cooperative nodes to CH, *E RCV _OH_ rcv _CH* $_{CCH}$ is received overhead energy consumption in the receive circuit of CH during the data collection from the cooperative nodes, similarly. *E TRANS_ OH_ trans _CH_ CCH* and E *TRANS _OH_rcv_ CCH_ CH* are the transmission side overheads. N_{CCH} is the number of cooperative nodes (in transmission mode $n_{CCH} = n_T - 1$ and in receive mode $n_{CCH} = n_R - 1$). In our model (without clusterheads), the energy consumption in a cluster j equals:

$$Energy\ consumption\ in\ cluster\ 'j' = E_{RCV\_coop}\left\{\sum_{i=1}^{N} l_i\right\} + E_{TRANS\_nodes}\left\{(Data\ sensed\ in\ cluster\ j)\right\} \quad (4)$$

From equation 4, we can prove that the proposed mechanism in clustering can save energy and increase the network lifetime by making direct transmission from all selected nodes, without relaying the data to clusterheads.

The equations for E_{TRANS} and E_{RCV} are:

$$E_{TRANS\_coop} = \left(\frac{1}{b}\left[\frac{\bar{P}_b}{\bar{\bar{N}}_e}\right]^{-\frac{1}{n_T n_R}} \frac{(1+\alpha)K'd^l}{\sin^2(\pi/M)} + \frac{P_{tx\_elect}}{R_b}\right) \times n_T \quad (5)$$

$$E_{RCV\_coop} = \left(P_{tx\_elect}/R_b\right) \times n_R \quad (6)$$

From equations 5 and 6, we can result that the energy consumption in our model depends on the number of cooperating nodes n_T, n_R and the distances between the clusters *d.* So reducing the number of nodes and the distance between the hops using the proposed selection mechanism will reduce the energy consumption.

4.2 Scalability

Glossy exploits constructive interference by rapidly propagating a packet from the sink node to all the other nodes through the entire network. The time slot T_{slot} between each hop includes the durations for data reception and transmission. The slot is a network-wide constant as it is determined by the packet length. In this way, Glossy attains near-optimal flooding latency. However, it is difficult to keep precise timing for multiple hops of concurrent transmitters in practice. Wang et al. [13] prove that glossy has a scalability problem. They define τ_e as the time uncertainty of the time slot T_{slot} in each hop. In Glossy, τ_e is calculated by the statistical uncertainty of the software delay τ_{sw}, the clock uncertainty τ_{tx} due to clock frequency drifts through the packet transmission, the radio processing uncertainty τ_d, and the propagation delay uncertainty τ_p. Therefore, we can write [13]

$$\tau_e = \tau_{sw} + \tau_d + \tau_{tx} + \tau_p \quad (7)$$

After *h* hops packet transmissions, the accumulated maximum time displacement Δ among concurrent transmissions to a common receiver is likely to exceed the threshold period T_c, giving rise to collisions. Also, as the number *m* of concurrent transmitters grows, the probability that the maximum time displacement Δ exceed the threshold period T_c for simultaneous transmissions also get higher. In Eq. (7), the software delay uncertainty τ_{sw} stand for the additional variation due to the unsynchronized clocks of the radio and the MCU. τ_{sw} is a discrete random variable with granularity $1/f_r$, where f_r is the radio clock frequency. It should be noticed that τ_{sw} can be perfectly eliminated with the new generation chips e.g. cc2530, which integrates MCU and radio modules in one chip with synchronized clock frequency. the radio processing uncertainty τ_d is a random variable with uniform distribution in the interval $[0;1/fr]$, caused by the offset between the asynchronous radio clocks of transmitter and receiver. τ_{tx} is the clock uncertainty in a packet transmission results from the clock frequency drifts due to temperature and aging effects.

In [29], the frequency drift ρ relative to the nominal frequency f_0 can be modeled as a Gaussian variable with distribution N(0;δ2ρ). It is reasonable to assume ρ is constant during a packet transmission time T_{slot}. Therefore, the clock uncertainty τ_{tx} due to the clock frequency drifts can be calculated as

$$\tau_{tx} = \int_0^{T_{slot}} \left(\frac{f_0}{f_0(1-\rho)}\right)dt - T_{slot} \approx \rho T_{slot}. \quad (8)$$

τ_p is the propagation delay uncertainty between the transmitted packets. The pmf p_e of the time uncertainty τ_e per hop can be calculated as the convolution of the pmfs of the aforementioned independent random variables. For a path of *h* hops, the probability mass function (pmf) of accumulated time uncertainty τ_e^h can be obtained by

$$p_e^h = \overbrace{p_e * \ldots * p_e}^{h} . \qquad (9)$$

From equation (7) we can realize that the τ_e is mostly influenced by the propagation delay between the multi transmitting signals; thus if we select the nodes which are almost at the same distance from the destination, the time offset between the arrivals of the signals shall be eliminated.

From equation (9), the reliability through multi hops is affected by the increasing of number of hops. By reducing the number of cooperating nodes using the proposed selection mechanism, the number of hops will decrease. This improves the PRR through a large scale network. Figure 8 illustrates the relation between PRR and maximum temporal displacement through different number of hops. The PRR decreases when number of hops increases.

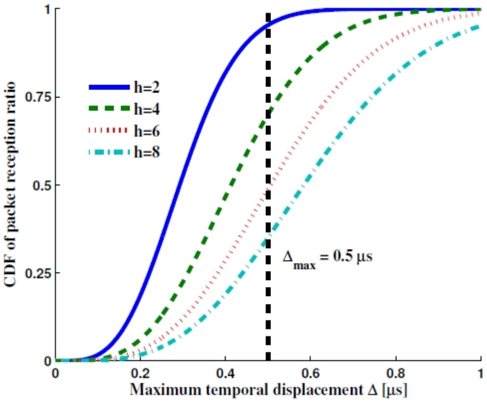

Figure 8: CDF versus Δ of different h (m = 5; N = 1) [13].

5. CONCLUSION

CI- based flooding is a promising that has been attracting large pool of researchers in recent years, due to its ability to realize near-optimal network flooding latency and sub-microsecond time synchronization accuracy. However, it consumes huge energy and suffers from the scalability problem. This paper proposes the first communication protocol that exploiting constructive interference, and including clustering and selection mechanisms which enhance the reliability and energy consumption of the CI-based flooding through a large scale network. Mathematical analysis shows that the proposed mechanisms improve the reliability of CI flooding for large scale networks, as well as reducing the energy consumption of the nodes. We are going to test this protocol in real time experiments to validate its efficiency in practice.

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