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Correlation-mode Gossip Protocol

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ABSTRACT

This disclosure describes a noise-tolerant gossip protocol suitable for a network of nodes communicating via noisy channels such as radio frequency or ultrasonic waves. The probability of error between two nodes is modeled as increasing with inter-node distance, mirroring the decay of electromagnetic or acoustic energy with distance. A node with information to transmit randomly selects one or more nearby nodes for reception, with the selection weighted towards lower error probability (geographically closer) nodes. A node that receives information retransmits the information to other nodes after confirming the veracity of the information by performing redundancy correction, e.g., by performing a majority vote over multiple receptions of the same information. The described gossip protocol achieves rapid, accurate, and stable convergence, e.g., each node of a network with geographically separated nodes rapidly receives the same, true information, even though the inter-node channels are of varying, possibly low, reliabilities.

KEYWORDS

- Gossip algorithm
- Gossip protocol
- Cloud computing
- Radio propagation
- Ultrasonic propagation
- Majority voting
- Redundancy coding
- Ultra-wideband (UWB) communication
- Ultrasonic communication

BACKGROUND

Gossip algorithms or protocols are techniques to communicate information over a wide network of nodes. In a gossip protocol, a node of the network periodically exchanges information with a subset of nodes, typically neighbors of the node, such that information hops across nodes to reach the ends of the network. A typical application is the transmission throughout the network of some information, e.g., a state change, that was updated at one node. Gossip protocols are appealing candidates for network-wide broadcast due to their simplicity, asynchronicity, stochasticity, ease of implementation, and the fact that each node only needs a local view of the network.

DESCRIPTION

This disclosure describes gossip protocol techniques for a cloud/device network based on correlation-mode information parsing. Example applications include nodes that communicate over distance or noise-aware modalities such as ultra-wide band (UWB) radio or ultrasound. In such scenarios, a node target-broadcasts an information-encoded pulsed waveform. Receiving nodes use correlation measures (e.g., matched filtering, envelope detection, etc.) to decode the information encoded in the pulsed waveform. The advantage of correlation-mode information parsing networks is that such transmitters/sensors are readily available as commodity hardware (not necessarily cloud computing servers), enabling the transfer of many cloud networking services to local edge servers. For example, the techniques enable an ecosystem of devices to form a mini-network for efficient computing.

The described gossip protocol is noise tolerant, with redundancy coding on real time, gossip state updates to enable near deterministic convergence to the true node state. Information is modeled as decaying with increasing inter-node distance, mirroring the decay with distance of radio frequency (or ultrasonic) signals. The probability of error thus increases with increasing inter-node distance. In each iteration of the described gossip protocol, a node with information to transmit (or relay) selects nodes that are close enough that their probability of error is sufficiently low. A receiving node receives the same information several times (e.g., three times), possibly from different transmit nodes, and uses the redundant receptions to correct errors. For example, if a receiving node received an information bit three times, it can perform a majority vote on the three receptions to determine the true transmitted bit. A node relays forward information it receives to other nodes after correcting errors, thereby reducing the propagation of errors through the network.

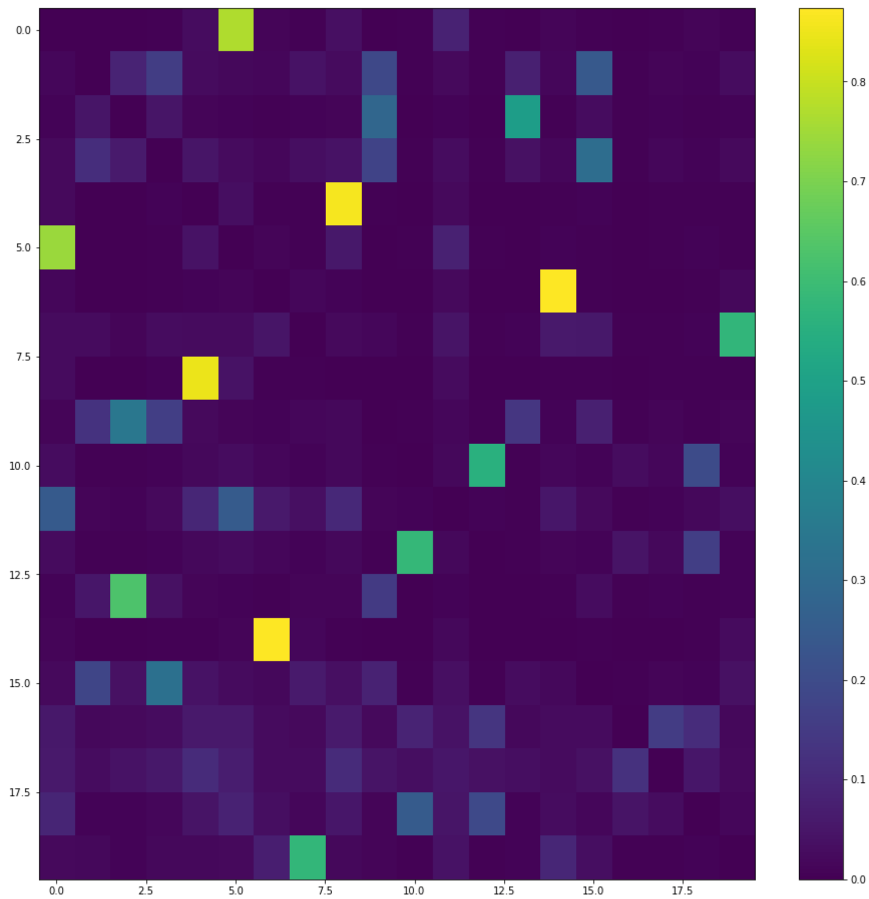

Fig. 1: A casting matrix, e.g., a matrix that shows the probability with which a transmit node *x* selects a receive node *y*

Fig, 1 illustrates a casting matrix, e.g., a matrix that shows the probability with which a transmit node *x* selects a receive node *y*. This example uses a twenty-node network. As explained earlier, the probability of error between a node *x* (indexed along the X-axis) and the node *y* (indexed along the Y-axis) depends on their Euclidean separation. A transmit node *x* can select a receive node *y* with high probability (yellow) if their distance is close (the error probability is low). A transmit node *x* can select a receive node *y* with lower probabilities (green, blue, purple) if the nodes are further apart (the error probability is relatively high). The diagonal of the matrix of Fig. 1 is zero since the probability of a node transmitting to itself is zero.

The matrix is symmetric, since the probability of error for a transmission from node *x* to node *y* is the same as the probability of error for a transmission from node *y* to node *x*. A row of the casting matrix, showing as it does the probability of selecting non-equidistant nodes for reception, forms a non-uniform probability mass function. A row of the casting matrix sums to unity, as does a column.

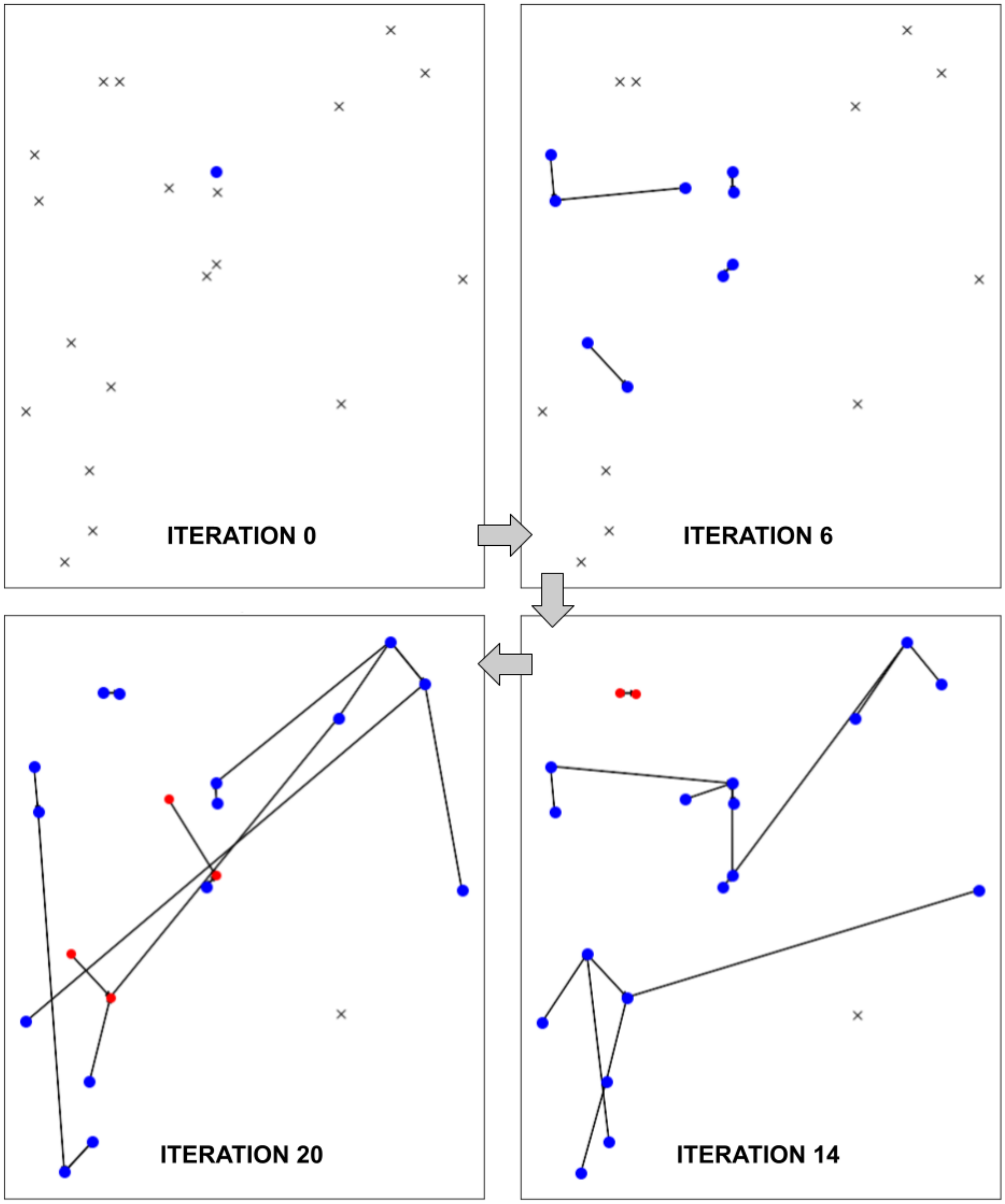

Fig. 2: Propagation of information through a network using a gossip protocol without redundancy correction

Fig. 2 illustrates, via simulation, the propagation of information through a two-dimensional, twenty-node network using a gossip protocol *without* redundancy correction. At iteration 0, a certain node (blue) originates information to be propagated throughout the network.

In this simulation, a given node selects just one other node to transmit or relay information to; the selected node is the one with the lowest probability of error.

By iteration 6, nine of twenty nodes have received the information, as it happens, without error. By iteration 14, seventeen of twenty nodes have received the information, but two have the information in error (red nodes). However, at iteration 20, the nodes that were in error in iteration 14 have corrected their errors. Due to nodes retransmitting without redundancy correction, errors have, however, propagated to other nodes in iteration 20, such that, as illustrated in Fig. 3, the network can reach a state of complete accuracy, e.g., all nodes having the same, true information, but can also re-diverge from the state of complete accuracy.

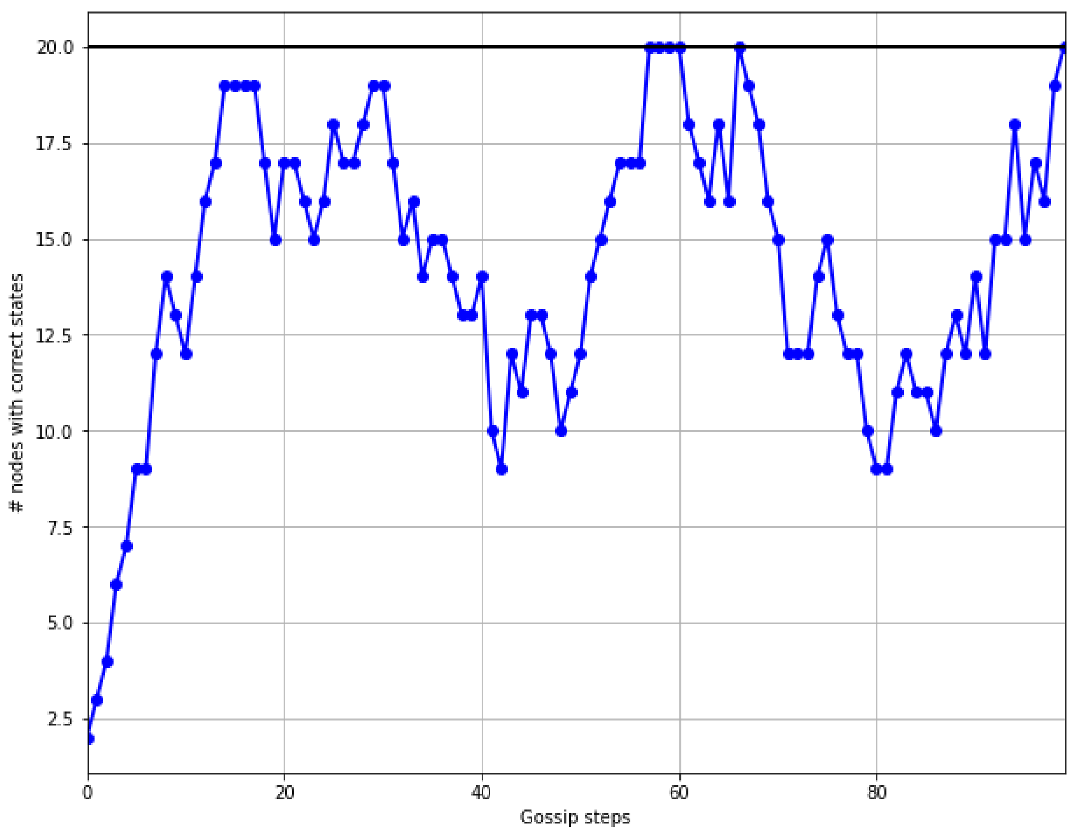

Fig. 3: Without redundancy correction, a network can reach a state of complete accuracy (iteration 57), but can re-diverge due to error propagation

Fig. 3 illustrates against time (iteration number) the number of nodes in the twenty-node network (of Fig. 2) that have received error-free information. Although the network reaches a state of complete accuracy (iteration 57), it re-diverges due to error propagation

With redundancy correction, e.g., a stipulation that a receiving node not re-transmit received information until it confirms the veracity of information by performing redundancy-based correction, e.g., majority over *n* receptions, the network achieves rapid, accurate, and stable convergence, as illustrated in Fig. 4.

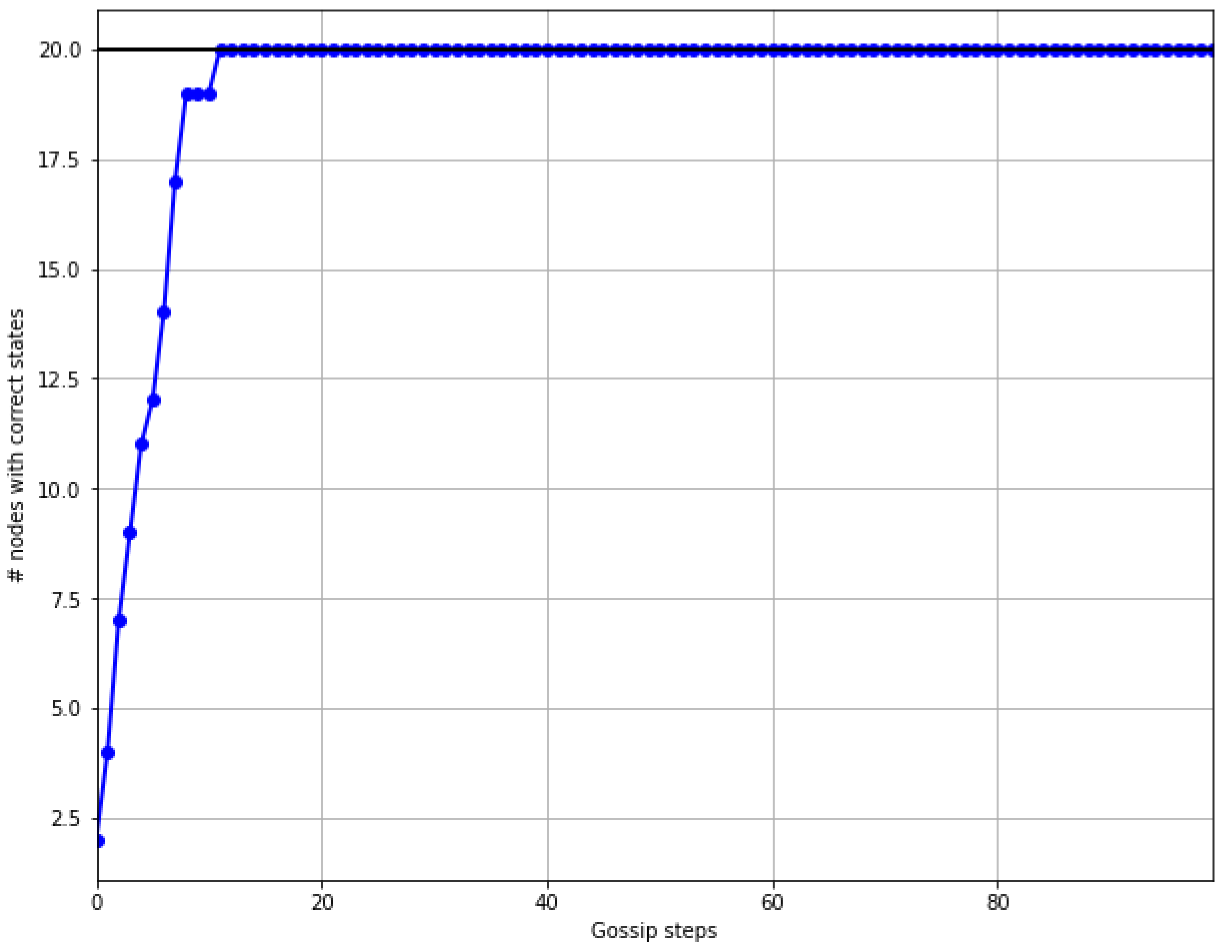

Fig. 4: With redundancy correction, the network achieves rapid, accurate, and stable convergence

Indeed, as illustrated in Fig. 4, the network converges within ten iterations, and further error propagation does not occur.

CONCLUSION

This disclosure describes a noise-tolerant gossip protocol suitable for a network of nodes communicating via noisy channels such as radio frequency or ultrasonic waves. The probability of error between two nodes is modeled as increasing with inter-node distance, mirroring the decay of electromagnetic or acoustic energy with distance. A node with information to transmit randomly selects one or more nearby nodes for reception, with the selection weighted towards lower error probability (geographically closer) nodes. A node that receives information retransmits the information to other nodes after confirming the veracity of the information by performing redundancy correction, e.g., by performing a majority vote over multiple receptions of the same information. The described gossip protocol achieves rapid, accurate, and stable convergence, e.g., each node of a network with geographically separated nodes rapidly receives the same, true information, even though the inter-node channels are of varying, possibly low, reliabilities.