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Contextual Gossip Protocol for Dynamically Changing Networks

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ABSTRACT

Gossip protocols are utilized to communicate information over a wide network of nodes. In a gossip protocol, a network node periodically exchanges information with a subset of nodes such that information hops across nodes to reach the ends of the network. In a dynamic network, a message-passing protocol that is not cognizant of the current network topology results in inefficient message propagation. This disclosure describes an efficient gossip protocol in which a global network is dynamically divided into subnetworks. Each message-transmitting node detects the subnetwork it currently belongs to. The node sets a higher priority of message-passing to nodes within its subnetwork. Subnetwork determination can be done by feeding user-permitted contextual information including motion, location, etc. to a trained machine learning model. The described techniques result in efficient message propagation.

KEYWORDS

- Gossip algorithm
- Gossip protocol
- Message-passing algorithm
- Dynamic network
- Internet-of-Things (IoT)
- Context determination
- Network topology

BACKGROUND

Gossip algorithms or protocols are techniques to communicate information over a wide network of nodes. In a gossip protocol, a network node periodically exchanges information with (passes messages to) a subset of nodes 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, and ease of implementation.

A seed node is a node with a message to pass. In a conventional gossip protocol, the seed node selects another node from the entire pool of nodes in the network. The probability of selection is uniform. The seed node then passes the message to the selected node. The node that receives the message becomes the new seed node and repeats the process.

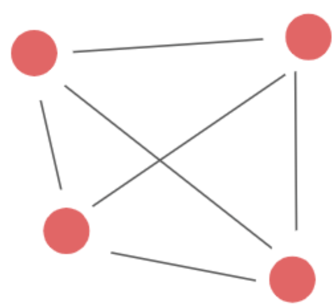

Fig. 1: A conventional gossip protocol

As illustrated in Fig. 1 and as mentioned before, in a conventional gossip protocol, a transmitting node selects with equal probability a receiving node out of the entire pool of nodes in the network. However, in many realistic scenarios, a single-network assumption can be inaccurate. Rather, the network can be more accurately modeled as a union of disjoint or partially joint subnetworks.

For example, a user may own multiple devices installed in their home, their office, their car, or other locations and may also carry mobile or wearable devices. As the user commutes from home to office, the topology of the global network comprising devices owned by the user changes. For example, while at home, a wearable sensor may be connected to a home-based smart speaker via Bluetooth, but while in the car the sensor loses connectivity with the smart speaker. Conversely, devices in the set of home-based devices maintain near-constant connectivity with each other and devices in the set of wearable devices maintain near-constant connectivity with each other, such that home-based devices and wearable devices each form distinct subnetworks. The subsets of home-based devices, office-based devices, car-based devices, wearable devices, or other subsets each form subnetworks that have time-varying degrees of inter-subnetwork connectivity.

Considering a user's devices as computing nodes, a message-passing protocol that is not cognizant of the current network topology can result in inefficient message propagation.

DESCRIPTION

This disclosure describes an efficient gossip protocol in which a global network is dynamically divided into subnetworks; a seed node detects the subnetwork it currently belongs to; and the seed node increases the priority of message-passing to nodes within its subnetwork.

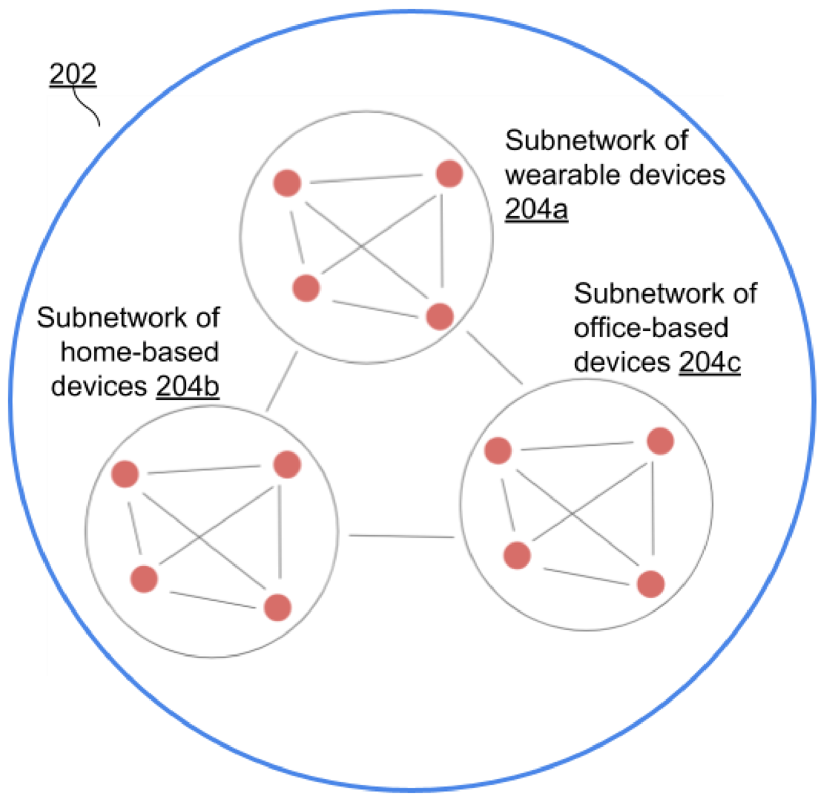

Fig. 2: A global network is divided into subnetworks

Fig. 2 illustrates dividing a global network (202) into multiple subnetworks (204a-c). Continuing the previous example of a user that owns devices installed in their home, office, car, and person, subnetworks can comprise, e.g., devices installed at home, devices installed in the office, wearable devices, etc. If the user is at home, the subnetworks of wearable devices and home-based devices can merge.

A device with a message to pass selects with greater probability a recipient node that is near to itself, e.g., within its current subnetwork. For message-passing to converge properly, e.g., such that all nodes eventually receive the message, message prioritization within subnetworks needs to be performed accurately, e.g., the changing subnetwork structure is to be baked into the gossip protocol.

In a contextual gossip protocol that is cognizant of the subnetwork structure of a global network, a seed node can execute the following:

- Determine the subnetwork that the seed node currently belongs to. As mentioned earlier, the subnetwork of a seed node comprises nodes that are most relevant, e.g., those in recent connectivity with the seed node and which can be prioritized for message passing.
- Select with a uniform probability another node within the subnetwork.
- Pass the message to the selected node.

The node that receives the message becomes the new seed node and repeats the above steps.

In this configuration, the network topology is dynamic. Even if a message converged in a subnetwork at time *t*, at time *t*+1, new nodes can enter (or leave) the subnetwork. For example, a user arriving home triggers the latching of home-based devices to the subnetwork of devices on the user. The message is to be propagated to nodes newly introduced into the subnetwork. Therefore, each seed node computes its current subnetwork dynamically.

With appropriate user permissions, dynamic subnetwork computation can be done using contextual cues, e.g., geographical cues derived from global positioning system (GPS), Bluetooth low energy (BLE), etc. A clustering technique can be applied to location information from a device to determine network topology, e.g., the subnetworks of a global network. Another contextual cue is motion, e.g., as derived from on-device inertial measurement unit (IMU) sensors. The network topology that includes the subnetworks of a global network, can be determined using the intensity of movement, three-dimensional degree-of-freedom (DoF) reconstruction that provides indoor movement direction, etc.

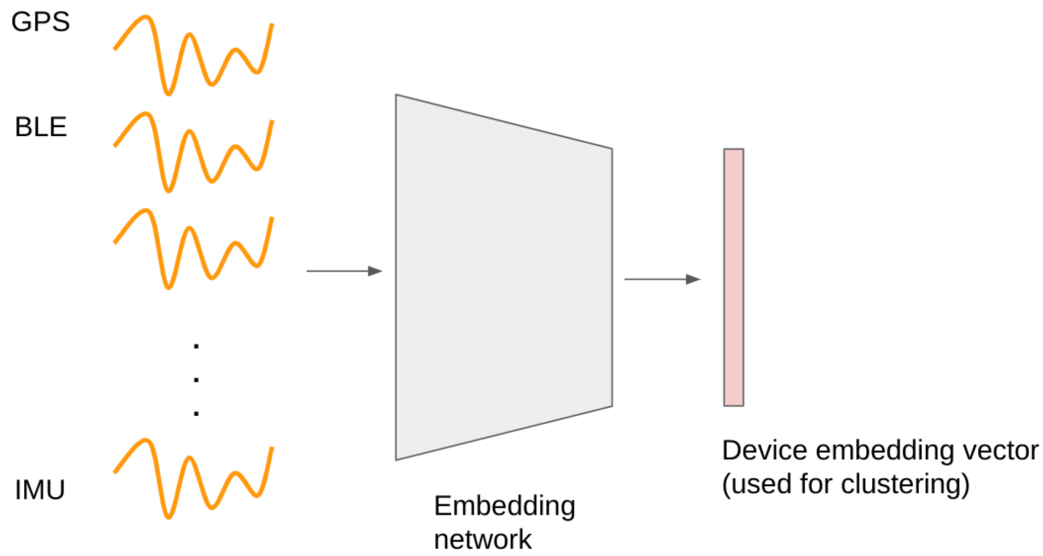

Fig. 3: Determining network topology using contextual information provided as input to a machine learning model

As illustrated in Fig. 3, contextual information from a GPS, Bluetooth, IMU, or other sensor, or other user-permitted information can be fed to an embedding network trained to output the subnetwork for a given node, e.g., the set of nodes that the given node belongs to. The output of the embedding network is a lower-dimensional feature vector amenable to matching (e.g., embedding-to-embedding comparison using L2-distance) to accurately identify subnetwork clusters at scale. Alternatively, subnetwork determination can be done with heuristics or other suitable techniques.

CONCLUSION

This disclosure describes an efficient gossip protocol in which a global network is dynamically divided into subnetworks; a message-transmitting node detects the subnetwork it currently belongs to; and the node increases the priority of message-passing to nodes within its subnetwork. Subnetwork determination can be done by feeding contextual signals including motion, location, etc. to a machine learning model. The described techniques result in efficient message propagation.

REFERENCES

[1] "Correlation-mode Gossip Protocol," Technical Disclosure Commons, (July 25, 2022) https://www.tdcommons.org/dpubs_series/5284 accessed Sep. 15, 2022.