A Network API-Driven Survey of Communication Requirements of Distributed Data Processing Algorithms for Sensor Networks

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In [105], we present the design of a sensor network application programming interface (API) to cover the common communication requirements of data processing applications in sensor networks, motivated by a study of all such applications proposed to date in the proceedings of Information Processing in Sensor Networks (IPSN). Due to space limitations, only a subset of the more than 100 papers surveyed are discussed in [105]. In this technical report, we present the full results of the survey.

To compile these results, we examined each paper proposing some sort of signal processing on data gathered by the sensor network, identifying the node-to-node communication patterns laid out by the authors. In all cases, we took great care to make as few assumptions as possible about the authors' intent; thus, only papers in which the required patterns are clearly specified appear in this survey.

A great deal of commonality can be found across the diversity of applications, and the destinations for node-to-node sending fall into three main camps: (1) address-based sending, where the target is specified as a single address or list of addresses, (2) region-based sending, where the targets are specified to lie in some region centered around the sending node or some arbitrary point in space, and (3) hierarchical sending, where the targets are specified as parents or children of the sending node based on associations between more- and less-powerful classes of devices. Each sending mode implies a reciprocal receiving mode for the target of the send; in addition, a subset of papers also employ eavesdropping receiving modes where a node which is not the intended destination of a message transmitted by nodes in its vicinity receives and examines the contents of the message.

We now present each API call, as proposed in [105], along with the list of references in which an instance of the associated communication pattern

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can be found.

1 Address-Based Sending

There are three principle destination types for address-based sending. The first sends a message to a single node address. The second sends a message to a single address that is a multicast address to which several nodes may be subscribed. The third sends a message to each of a list of node addresses. The calls for each of these send types are specified as follows:

sendSingle(*data*, *address*, *effort*, *hopLimit*). The parameter *data* is a pointer to the buffer chain containing the message data. *address* is the single-address destination for the message, drawn from the physical node address space. *effort* is an integer specifying the transmission effort level to use at each hop (1 to *MAXLEVEL*). *hopLimit* is an integer specifying the maximum number of hops over which the message may be forwarded on its way to the destination address (1 to *MAXHOPS*). [55, 12, 49, 77, 16, 61, 93, 11, 117, 13, 5, 6, 30, 53, 62, 66, 104, 47, 85, 81, 107, 63, 21, 110, 42, 50, 54, 68, 4, 33, 43, 7, 10, 27, 24, 115, 51, 80, 25, 94, 92, 78, 119, 58, 48, 57, 112, 64, 39, 17, 29, 26, 109, 40, 73, 84, 14, 103, 98, 101, 28, 59, 70, 106, 86, 20, 19, 18]

sendMulti(*data*, *address*, *effort*, *hopLimit*). The parameters here are as in *sendSingle*() above, except that *address* is drawn from the multicast-group addressing space. [49, 93, 66, 68]

sendList(*data*, *addList*, *effort*, *hopLimit*). The parameters here are as in *sendSingle*() above, except that *addList* is a pointer to a buffer chain containing the list of destination addresses drawn from the physical node address space; the number of addresses in the list can be determined from the length of the data (in bytes) in the *addrList* buffer chain. [12, 53, 66, 104, 110, 33, 24, 115, 80, 25, 95, 119, 112, 109, 98, 101, 106, 18]

2 Region-Based Sending

Applications may often want to address all nodes within certain geographic constraints. This may include all nodes within a certain number of hops of a given node, all nodes within a certain radius of a given node, or all nodes within an arbitrary region of space. The API calls to support this are specified as follows:

sendHopRad(*data*, *hopRad*, *effort*, *hopLimit*). The parameters here are as in *sendSingle*() above, except that *hopRad* is an integer specifying a hop-count from the sending node within which all neighboring nodes are intended to receive the message. *hopRad* can take a value ranging from 1, corresponding to immediate radio neighbors, to *MAXHOPS*, corresponding to a network-wide flood. [49, 46, 76, 5, 11, 89, 6, 62, 87, 97, 99, 100, 90, 41, 83, 50, 54, 79, 27, 24, 51, 45, 15, 67, 74, 36, 8, 113, 92, 48, 116, 17, 64, 39, 60, 29, 102, 26, 109, 103, 98, 114, 106, 86, 19]

sendGeoRad(*data*, *geoRad*, *outHops*, *effort*, *hopLimit*). The parameters here are as in *sendSingle*() above, except that *geoRad* is a floating point number specifying a geographic distance (in standardized units) from the sending node within which all neighboring nodes are intended to receive the message, and *outHops* specifies the maximum number of hops that packets are allowed to propagate outside the specified region in order to route around voids inside the region, attempting to reach all intended nodes. [49, 69, 2, 15, 8, 106]

sendCircle(*data*, *centerX*, *centerY*, *radius*, *single*, *outHops*, *effort*, *hopLimit*). The parameters here are as in *sendSingle*() above, except that *centerX* and *centerY* are floating point numbers that define the coordinates of the center of a circle, and *radius* is a floating point number specifying the radius from that point within which all nodes are intended to receive the message (all in standardized units). *single* is a boolean flag indicating how many sensors in the area must be reached: *single = 1* specifies that only one sensor in the area must receive the message, whereas *single = 0* specifies that all sensors in the area are intended to receive the message. [82, 49, 69, 66, 68]

sendPolygon(*data*, *vertCount*, *vertices*, *single*, *outHops*, *effort*, *hopLimit*). The parameters here are as in *sendSingle*() above, except that *vertCount* is an integer specifying a number of polygon vertices (1 to some number *MAXVERTS*), and *vertices* is a pointer to an array of floating point numbers representing the spatial coordinate pairs of the vertices (in standardized units). *single = 1* specifies that only one sensor within the convex hull formed by the vertex list must receive the message, whereas *single = 0* specifies that all sensors in this area are intended to receive the message. [49, 110, 68, 66, 43]

3 Device Hierarchy Sending

In any sensor network, there will typically be a hierarchy induced by a central data sink and the nodes of the network. In a sensor network with multiple classes of non-sink devices (e.g., low power sensor nodes and higher power intermediate nodes), we support extending this device hierarchy to reflect these additional device classes. The API calls for sending in the device hierarchy are specified as follows:

sendSink(*data*, *effort*, *hopLimit*). The parameters here are as in *sendSingle*() above. The message is sent to the "best" available sink node in the network, where the choice of sink node is determined for the application by the API. [71, 55, 49, 77, 56, 23, 61, 91, 62, 108, 88, 107, 81, 63, 3, 110, 72, 38, 4, 44, 27, 15, 22, 95, 119, 58, 65, 52, 60, 102, 103, 101, 31, 35, 106, 118, 34, 32]

sendParent(*data*, *effort*, *hopLimit*). The parameters here are as in *sendSingle*() above. The message is sent to the node's parent in the device hierarchy. [108, 21, 116, 75, 52, 9, 1, 37, 32, 111, 96]

sendChildren(*data*, *effort*, *hopLimit*). The parameters here are as in *sendSingle*() above. The message is sent to each of the node's children in the device hierarchy. [108, 52, 9, 37, 32]

4 Receiving

A node can receive a message for which it is the target destination. In addition, it can also passively eavesdrop on all messages overheard by the node's radio receiver. The API call for receiving such messages is specified as follows:

receiveOverhear(*data*, *metadata*). The parameter *data* is a pointer to a buffer chain holding the message data, and *metadata* is a pointer to a buffer chain holding the header information appropriate for the message packet type. This API call is invoked by the API implementation as an event into the application when a message has been received. Any message overheard by this node's radio will be received, regardless of the addressing of the message. [49, 50, 108, 80]

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