Poster: Smart Self-Adaptive Clustering Technique for Collaborative Sensing in IoT Risk Contexts

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Abstract

In this work the integration of a modular and flexible WSN hardware platform with a smart wearable device for IoT application prototyping is leveraged to introduce a new adaptive hybrid clustering technique for mesh collaborative networks. The proposed dynamic dissemination strategy attempts to efficiently support on-site data provision considering the location variability of smart mobile devices relative to deployed stationary sensor nodes, with a particular application use case: risk scenarios.

1. Introduction and Motivation

In the ongoing era of the Internet of Things (IoT) new technological approaches have to be considered in order to properly face the challenges of smart networking scenarios, where the participation and interaction of users, i.e. mobile agents, with sensors and deployed devices, demands the creation of more dynamic and evolvable systems. This is particularly important when performing distributed data dissemination strategies in collaborative mesh networks.

In traditional Wireless Sensor Networks (WSNs), cluster-based routing protocols provide a way to increase energy efficiency, reduce the network traffic load and improve its scalability. Clustering techniques rely on dividing the network into different groups of nodes which have a so-called Cluster Head (CH) and a set of regular member nodes. The main concern in this type of strategies is the efficient selection of the clusters roles, so that a well-balanced system can be achieved. Different ways of tackling this problem have been proposed in the literature, such as PEGASIS [1] or HEED [2]. However, these traditional works do not consider the mobility and variability of the nodes that is intrinsic to the novel smart dynamic environments, which makes mandatory the runtime adaptation of the data dissemination process.

Taking advantage of the flexibility and modularity of a novel development platform for IoT, a hybrid routing and dissemination algorithm is proposed in this work, in which mobile and intelligent wearable nodes are used as the core of a clustering scheme for participatory sensing scenarios, eliminating the need to accomplish the CH negotiation mechanism. Clusters are created dynamically according to the relative position of the smart wearable devices with respect to the deployed sensor nodes, which provide an adaptive distribution of the data paths.

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Although this proposal simplifies the cluster creation process, the mobility of the CH introduces new challenges, which have to be considered and faced in order for the algorithm to be robust and adaptive to the diversity of possible scenarios. In particular, this solution is oriented towards critical application use cases, where individuals operating within moderate mobility margins can gather sensing information directly from the deployed WSN for risk detection and notification in such critical contexts.

2. Reference System Architecture

The proposed system is essentially supported by a WSN platform called *Cookies* [3] and a smart wearable device, the *Hexiwear* [4], whose integration conforms the basis of a work-in-progress IoT development framework for smart applications. The *Cookie* node is a modular and reconfigurable HW/SW platform for WSN prototyping, while *Hexiwear* is a device designed to combine the characteristics of a smart wearable with those of a sensor node. It includes the IEEE 802.15.4 standard into its architecture, allowing a direct communication with WSN-based systems. The combination of these two platforms results in a flexible and robust framework for IoT.

3. Clustering Approach

The main idea behind this work is based on the dynamic creation of sensing clusters by smart wearable devices, and the implementation of a novel routing approach to respond robustly to their associated mobility. The *Hexiwears* are used as adaptive CHs to support data transmission between any points of the mesh network. The hybrid solution firstly involves the definition of action zones (*Az*), which contain at least one mobile node that functions as CH. Messages from *Az* are either sent directly to the gateway (GW), or indirectly by using other CHs. Cluster Linker Nodes (LNs) are considered in case of no other CH can be reached, as well as intra-cluster routing (iCR) for enhancing cluster integrity. The algorithm is divided into three phases:

a) Deployment configuration phase: In this initial phase a series of advertisement messages are sent among the stationary/normal nodes (*Cookies*) to establish a first-stage

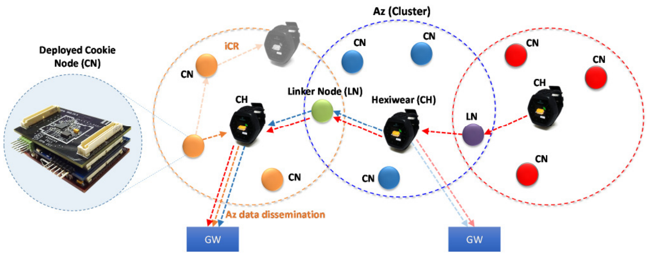

Figure 1. Clustering formation and adaptive data dissemination

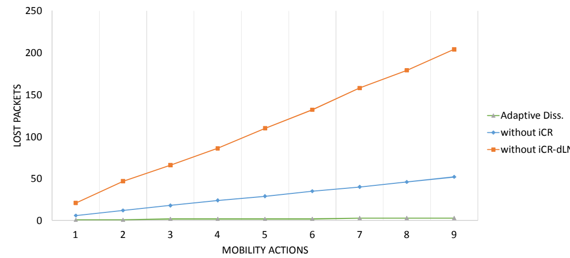

Figure 2. Results comparing accumulative lost packets when applying normal vs. adaptive data dissemination

communication and location map throughout the enclosed environment. Neighbor discovery replies include connectivity metrics (RSSI, LQI and LDR) that will be used in the intra-cluster routing mechanism, if necessary.

b) Mobile discovery phase: Mobile nodes send discovery messages from a certain position in their action zone to create new clusters with the normal nodes that are within the discovery message range. These stationary nodes respond to the discovery messages and, after a timeout t_c, the smart mobile node creates a cluster (thus acting itself as CH) and the stationary nodes as cluster participants. It then sends the cluster information to the participant nodes so that all of them register the cluster they belong to and the nodes that compose such cluster. Stationary nodes that receive more than one discovery message from different CHs send a linker request to become a LN between both CH. If there is no LN for those adjacent *Az* the request is accepted, then the node becomes a LN between both CHs.

c) Adaptive data dissemination phase: as shown in fig. 1, the mobile devices collaborate in disseminating data related to their working areas by sending messages through single-hop connections among them or through LNs. The wearable nodes allow direct notification of risk events to the users at runtime, based on the measurements sent by the stationary nodes to the CHs, as well as the state of the rest of the zones. These packets sent by the stationary nodes are also important for the adaptive data dissemination required by the mobile nodes, as CHs compare the link quality and radio signal metrics of the discovery phase with the current values of the received packets, and in the case that the variability of connections gets over a certain threshold (more than j nodes that belong to Az_n have $Qm < Qm_{TH}$), a new clustering process is triggered to respond to the movement of the wearable device to a new *Az.* Also, when the mobility of the CHs occurs within the cluster limits, participant nodes can route the messages internally throughout the cluster, forwarding the packets to the CH, so that momentary changes in the position of the mobile node do not affect the overall data provision of the cluster. This internal iCR scheme relies on the information obtained in the first phase by the Cookies to efficiently decide which participant node forward the internal packet to the CH.

4. Experimental Evaluation

Experiments have been carried out at CEI-UPM using 7 *Cookie* nodes and 2 *Hexiwears*, and fig. 2 represents how the mobility of the wearable nodes (represented as the variability of distance between the actual position of CH and the position of the CH when the cluster was created) affects the packet delivery performance of the network in contraposition with the inclusion of adaptive dissemination strategies. The number of accumulative lost packets when a variation of the CH position occurs within its action zone and a participant node cannot deliver its associated data to such CH (no iCR) are shown in blue color, while green shows lost packets when intra-cluster routing is used, thus having a more efficient response to mobility events and increasing the chance that packets of normal nodes reach their CH. In red the lost packets in case changes in the position of both CHs happen and no dynamic selection of LN is performed, so data delivery between *Az* is penalized.

5. Conclusions and Future Work

The mobile clustering technique for IoT collaborative sensing introduced in this work opens up new approaches for efficient data dissemination among sensor nodes and smart wearable devices in mesh networking applications, where mobility is inherent. Additional experimental tests are currently in process to further study the adaptability of the proposed system considering different deployment scales, distribution and event-detection patterns.

6. Acknowledgments

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7. References

[1] R. K. Yadav, A. Singh. 2016. Comparative study of PEGASIS based protocols in wireless sensor netwroks. In Conf. Information Processing (IICIP), pp. 1-5.

[2] O. Younis, S. Fahmy. 2004. HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks. in IEEE Transactions on Mobile Computing, 3 (4), 366-379.

[3] G. Mujica, J. Portilla and T. Riesgo. 2015. Performance evaluation of an AODV-based routing protocol implementation by using a novel in-field WSN diagnosis tool. In Microprocessors and Microsystems Journal, 39 (8), 920-938.

[4] Hexiwear, IoT and wearable development solution, http://www.hexiwear.com/