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Content Centric Framework for Wireless Sensor Networks

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Abstract: An application specific Wireless Sensor Network (WSN) is a combination of few to large number of sensor nodes deployed in certain geographical region along with a sink node either within or outside that region of deployment. The sole objective of the sensor nodes is to collect the desired data from the environment and transmit that to the nearby sink node for further information extraction and forwarding to the subscriber's location periodically. However, the periodic updating might be irrelevant for the subscribers. In this process there is unnecessary wastage of battery power of the sensors as well as degradation of the performance of the sink node. In our proposed content centric framework we have addressed the issue by considering the Cluster Head (CH) nodes among a group of nodes, processing the received data from the sensors and forward the information to the sink node based on the desired attributes of the subscribers. The filtration mechanism not only reduces the wastage of the battery power but also enhances the network life time as well as the bandwidth utilization in the network. From the simulation it has been observed that our CCN outperforms the traditional based periodic communication model.

Key words: Wireless sensor network, routing node, cluster head, ETX, CCN, simulation

INTRODUCTION

In the recent technology Wireless Sensor Networks (WSN) play an important role for monitoring the natural phenomena like temperature, humidity, pressure, earthquake and other things for our physical environment (Dalei *et al*., 2017). The Wireless Sensor Networks (WSN) are usually formed by setup of sensor devices and one or more base station or sink node. In traditional wireless sensor network in Fig. 1. Sensor nodes collect data from the real world environment and transmit to the other sensor nodes or sink node directly or indirectly (Dalei *et al*., 2017). Sometimes these data may not be useful by the sink node. So, sink node simply drops these packets, this leads wastage of energy and bandwidth of the sensor nodes as well as base station. Researchers have designed many content oriented routing protocols using publishers/subscribers framework to reduce the unnecessary transmissions (Taherian and Bacon, 2007).

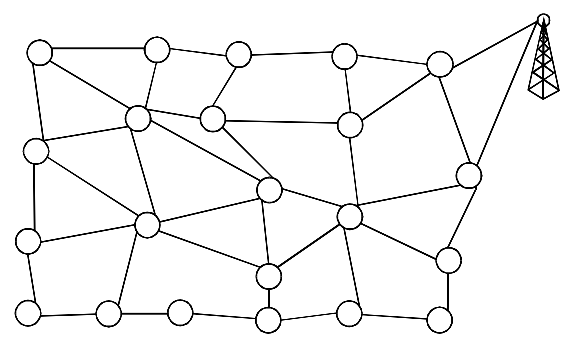

Fig. 1: Traditional WSN

In traditional publishers/subscribers model (Sheltami *et al*., 2016) subscribers subscribe or request a specific interests or query to the publishers/subscribers network. The publishers/subscribers networks contain different types of topic based data which is collected from the sensor network and it is referred as publishers of the given network as in Fig. 2.

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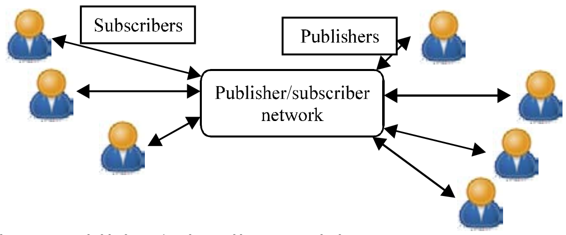

Fig. 2: Publisher/subscriber model

The subscriber injects the content into the publisher/subscriber network which is classified as one of the topic and then filtered and transmitted to the respective subscriber (Aguilera *et al*., 1999). The publisher/subscriber architecture is broadly classified into two types:

- Content based publisher/subscriber
- Topic based publisher/subscriber

Content based publisher/subscriber: In this architecture the subscribers have more flexibility and more power to customize the needed contents (Ma *et al*., 2014). Each subscriber has to subscribe its required interests or content using a set of attributes values or key values. The subscriber query is defined as set of attributes, i.e., where S-id is the subscriber identification and A_1, A_2, ..., A_n represent attributes. Each attributes consists of {data type, attribute name, value}. The publisher data consists of set of attributes which is expressed as a quad {data type, time, attribute value, id}.

Topic based publisher/subscriber: In this architecture the publisher's data are classified into different categories on the basis of context of data (Chen *et al*., 2013). Each category is referred as one class or topic. The subscriber has to subscribe the class or topic depending on requirement.

Depending upon the interaction of publishers and subscribers the publisher/subscriber architecture is classified into three types centralized publisher/subscriber multiple publisher/subscriber and peer-to-peer publisher/subscriber.

Centralized publisher/subscriber: In this architecture there will be a one centralized publisher/subscriber network. All the subscribers and publishers are connected to the centralized publisher/subscriber (Hunkeler *et al*., 2008).

Multiple publisher/subscriber: In this architecture multiple publisher/subscriber models are present in network. All publishers and subscribers are connected one of the publisher/subscriber network.

Peer-to-peer publisher/subscriber: In this architecture the publishers and subscribers are connected each other directly (Yasar *et al*., 2011).

Literature review: Many publisher/subscriber modes are implemented in large scale wireless sensor network to reduce the routing overhead to increase the throughput of the network and reduce the wastage of energy. In this study, we have discussed many existing publisher/subscriber networks (Hall *et al*., 2004).

In mires (Souto *et al*., 2005) the transmission take place with respect to topic which is described by the subscribers. The mires is a publisher/subscriber framework which is based on topic that is context of the data. It minimizes the number of transmission because only the topic subscribed by the subscriber is sent back to the sink node. In mires (Souto *et al*., 2006), the publishers and subscribers data transmission path is known to each other.

The TinyMQ (Shi *et al*., 2011) is content centric network which implements the publisher/subscriber method in wireless sensor network. In this model the sensor node behaves like publisher as well as subscriber by exchanging the event and query with each others. The TInyMQ is designed using two layers architecture, one layer is known as addressing layer which is responsible for assigning unique addresses to each of the sensor node. The other layer is known as publisher/subscriber layer which is responsible for messages transmission between subscriber and publishers.

The PUB-2-SUB (Tran and Pham, 2009) is a publisher/subscriber model which is suitable for point-to-point network. In this model a tree is created to represent the whole network and the data. A indexing is maintained to identify the subscriber request and give the notification which path the query is forwarded. The main advantages of this model is load balancing and data availability.

The TinyDDS (Boonma and Suzuki, 2010) is an extension of topic based DDS which is publisher/subscriber model. It provides accessibility between the wireless sensor network and outside network. The publisher publish the data according to the dynamic condition of the network. The main function of TinyDDS to provide the portability to the access network where the subscribers is connected with this network.

MATERIALS AND METHODS

Proposed algorithm

Content centric framework for wireless sensor network: Content Centric Framework (CCF) is new networking model to provide general platform for subscriber to get the specific content from the network. In this study, we

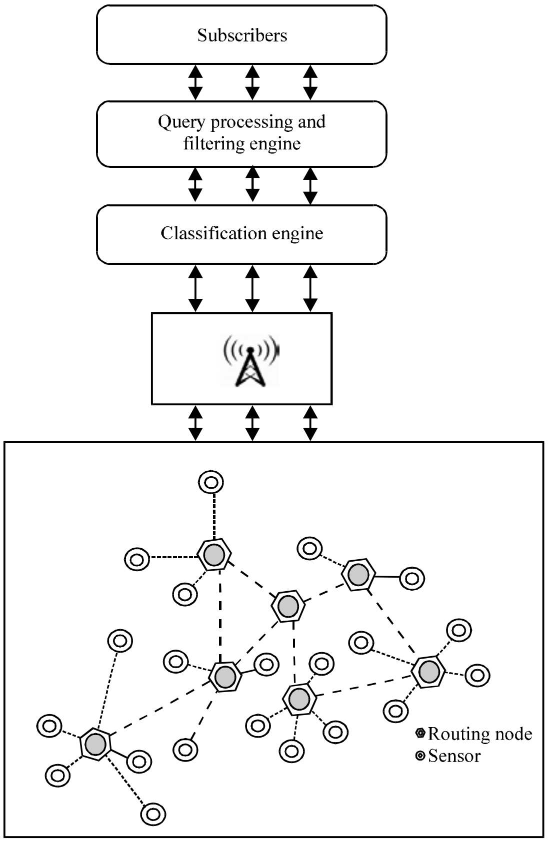

Fig. 3: Proposed network model

have designed a general content centric architecture for efficient communication and secure transmission. The main objectives of this architecture to provide the following functionality such as:

- No end-to-end connection is required
- The live data is available in different component of this model
- Load distribution is uniformly maintained throughout the network
- Only the routing node transmits the data to the sink node

The sensor network model: The sensor nodes are distributed in random deployment manner in rectangular area. In whole network randomly only 5% nodes are selected as Routing Nodes (RN) or Cluster Head (CH). Once the cluster head selection is done then clusters are created using the euclidian distance or Receiving Signal Strength Indicator (RSSI) as shown in Fig. 3. The cluster head can transmit the data directly to the sink node or through the intermediate cluster head (Boonma *et al*., 2010). Each cluster head or routing node maintains a routing table regarding the reliable route to the other cluster heads or other routing nodes. Each routing node can select the reliable route (Esposito *et al*., 2013) to other routing node using the Expected Transmission (ETX) metric (De Couto *et al*., 2003). The ETX metric is defined as follow:

- Let D_F be the packet reception rate on a Forward direction
- Let D_R be probability getting acknowledgment in Reverse direction
- Using bernoulli trail the expected number transmission is defined as ETX = $1/DR_i \times DF_i$
- The ETX on a route-i is defined as $ETX_i = \sum_{i=1}^{n} (1/DR_i \times DF_i)\ \forall_i = 1, 2, 3, ..., n$
- The optimal ETX of a graph is defined as Min $\sum_{i=1}^{n} (1/DR_i \times DF_i)$ subject to: $1 \leq D_R > 0$; $1 \leq D_F > 0$

The routing node selects an optimal ETX path to transmit the live data to the sink node or other routing node or cluster head.

The classification engine: The Classification Engine (CE) collects the data from the sink node and classifies the data according to the subscriber's requirements. The classification engine maintains a handling queue to put the data into different queue depending on the context of data. For example audio data put into audio queue, image data put into image queue and numerical and text data put into text queue. The following illustration is given for handing different data for each subscriber as follow:

$$S = \{s_1, s_2, s_3, ..., s_n\}$$

Sensed data:

$$Q = \{q_1, q_2, q_3, ..., q_n\}$$

Queried for sensed data:

$$Q_i = \{q^1_i, q^2_i, q^3_i, ..., q^n_i\}$$

type of query for subscriber i, $\forall_i = 1, 2, 3, ..., n$. The data classification is done using Decision Tree (DT) which creates a different partition at the leaf level to the different classes (Bishop, 2006). The portion is done either using a single attribute or multiple attributes depending on the requirement of the subscribers.

Filtering engine: The data is collected from the classification engine module and filter depend on the exact content of the subscriber query (Tran and Pham, 2010). The subscriber injects the query into the query processing and filtering module using a set of attributes which is define as follow:

$$\text{Subscriber}_{\text{attributes}} = \{\text{S-id}, A_1, A_2, A_3, ..., A_n\}$$

Filtering algorithm:

1. Matching _attribute [i] = ø
2. Assume that n number of subscribers
3. for (i = 1; i≤n; i++)
4. {
5. if (classified$_{data}$∩Subscriber (i). Query! = empty)
6. {
7. Matching_attribute [i] = True
8. Subscriber [i].query = Matching_attribute [i]
9. Publish (sensed_data)
10 }
11 Else
12. {
13.Matching_attribute [i] = False
14. Ignore (sensed_data)
15. Notification (Subscriber [i]) = False
16. }
17. }

RESULTS AND DISCUSSION

We have implemented this model on MATLAB with comparison on traditional Content Centric Network (CCN). For our simulation we have taken 100 sensor nodes. Randomly we have selected 5% node as cluster head or routing nodes in every round depending upon their residual energy and transmission range. In this simulation we have considered a sensor field of size 100×100 m^2 with random deployment of sensor nodes. The simulation parameter table is given in Table 1.

In Fig. 4, at 1500 rounds the number alive nodes become zero for traditional content centric network where as the number of alive node in our proposed framework is zero at 2500 rounds. In Fig. 5, the number of dead nodes is 100 at rounds 700 where as our proposed model the number of dead nodes is 100 at rounds 2500. This implies more live data is available in our proposed mode.

In Fig. 6, the residual energy of the sensor node after each round become zero at 1500 rounds in case of traditional content centric network but our proposed model the residual energy of sensor node become zero at 2500 round. So, the life span of the network is more in the proposed model. In Fig. 7, the throughput of the network is defined as number packets are transmitted per each round. In Fig. 7 using traditional content centric network the number of packets are transmitted per each round is almost 2.5×10^4 where as the number of packets are transmitted per round is almost 9.5×10^4. In Fig. 8, the success rate which is defined as the number of packets is received at the destination. So, our proposed model the success rate is increased in every round.

Table 1: Simulation parameter

Parameters name	Parameter value
Number of sensor nodes	100
Sensor field size	100×100 M^2
Initial energy	0.5J
Number of cluster head per round	5%
Data aggregation	5 nJ/bit/signal
Transmitter amplifier between CH and sensor node	0.005pJ/bit/m^2
Transmitter amplifier between Ch and Sink node	10 pJ/bit/m^2

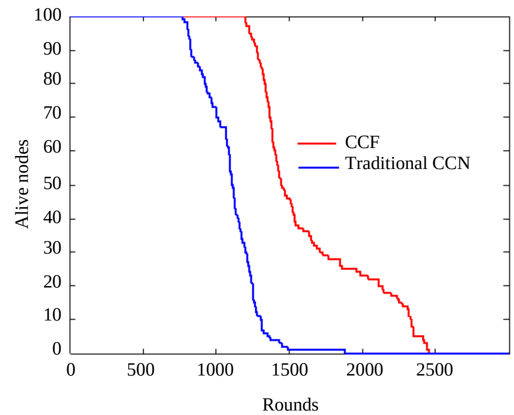

Fig. 4: Allive nodes

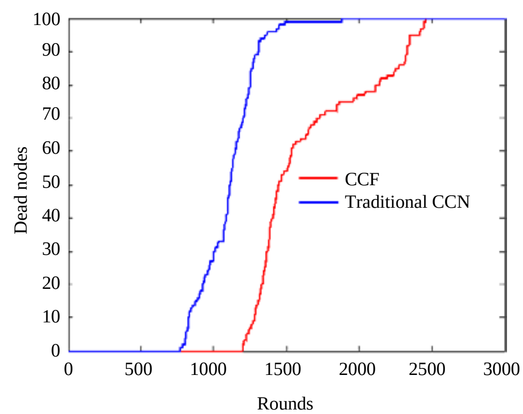

Fig. 5: Dead nodes

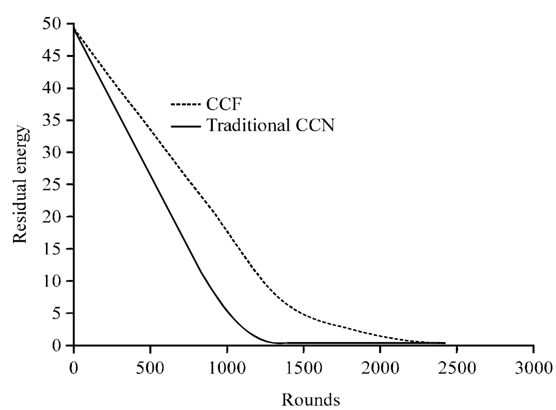

Fig. 6: Residual energy

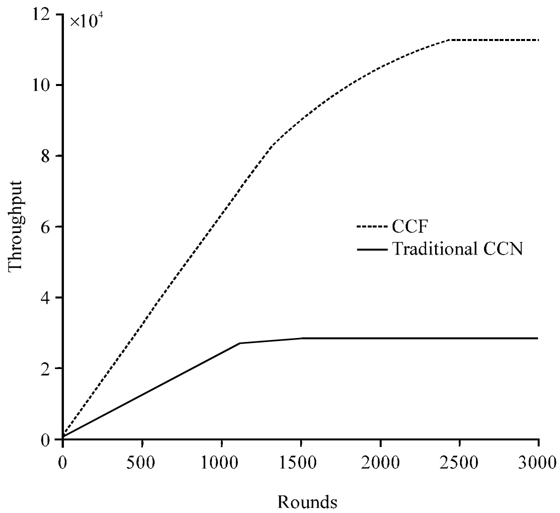

Fig. 7: Throughtput of network

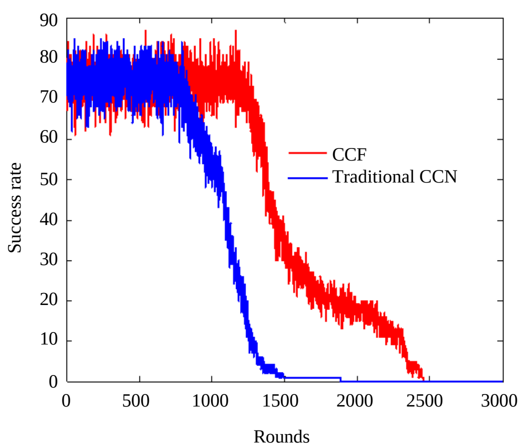

Fig. 8: Number packets reached at destination

CONCLUSION

In our study, we have reviewed many publisher/subscriber models which are implemented in wireless sensor network. In each publisher/subscriber model the subscribers query is matched with the sensed data and transmit to the respective subscriber. In each of the existing model reliability of path selection is not tested and sometimes the data may not be successfully reached at destination. In our proposed framework we have implemented the ETX metric to test the reliability of path selection before transmitting the data to the sink node. In our simulation result we have shown that the success rate of our proposed model is much better than the existing publisher/subscriber models.

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