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Classification Method in Integrated Information Network Using Vector Image Comparison

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Abstract: Wireless Integrated Information Network (WMN) consists of integrated information that can get data from its surrounding, such as image, voice. To transmit information, large resource is required which decreases the service time of the network. In this paper we present a Classification Approach based on Vector Image Comparison (VIC) for WMN that improve the service time of the network. The available methods for sub-region selection and conversion are also proposed. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Wireless integrated information network, Characteristic vector, Vector image comparison.

1. Introduction

Wireless integrated information network (WMN) consists of hundreds or even thousands of integrated information nodes that are powered by small irreplaceable batteries. The integrated information, which is randomly deployed in an environment, should collect data from their surrounding, process the data and finally send it to the sink through multi hops [1]. There are many applications where integrated information nodes are deployed onto roads, walls or unreachable place and they sense a variety of physical phenomena such as traffic on the road, temperature, pressure or detect forest fires to aid rapid emergency response. WMN has limited resources such as less communication bandwidth, limited resource supply, less storage and less computing power [2].

Wireless integrated information network (WMN) has been possible due to the production of cheap CMOS (Complementary Metal Oxide Semiconductor) camera and microphone integrated information which can acquire information. WMN consists of camera integrated information as well as scalar integrated information. Camera integrated information can retrieve much richer information in the form of images or videos and hence provide more detailed and interesting data about the environment [3]. Scalar integrated information can retrieve the scalar phenomena like temperature, pressure, humidity, or location of objects [4]. Camera integrated information may generate very different views of the same object if they are taken from different viewpoints [5].

Integrated Information Nodes (IIN) are deployed in remote and hostile environment, so it is difficult to replace the batteries. They are densely deployed to get the physical environment. In case of WMN, the neighboring integrated information would produce similar data and transmit such data to the sink. During this transmission of data, a large amount of resource is consumed. To reduce the resource consumption some kind of grouping of integrated information nodes can be done to form components. Inside every component, one node acts as sub-region (CH). Sub-region is responsible for communication with other sub-regions. Sub-region collects data from all the nodes within its component aggregates this information and then transmits to the sink through other CHs using multi hop communication [2]. Fig. 1 shows the Classification of nodes in a general WMN. In WMN, the volume of data to be transmitted is very large, therefore, more resource consumption occurs during communication [6].

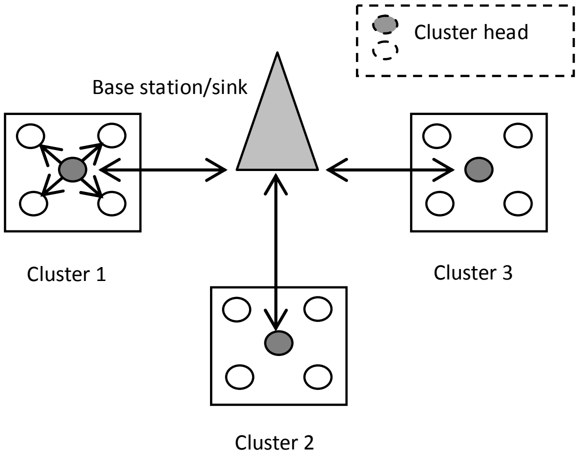

Fig. 1. Cluster of SNs in WMN.

In this paper, we propose a Classification and sub-region selection approach. Vector image comparison (VIC) technique based upon characteristic values. VIC method has been used in many applications such as image segmentation, social networks, etc. [2].

The vector image comparison (VIC) algorithm is based on second highest characteristic values of particular image. The second smallest characteristic value of the Kirchhoff's matrix corresponding to different characteristic vectors, is used to partition the image into two parts. Within a component, a node with highest characteristic value is selected as sub-region. In case of WMN, large volume of sensed data is generated, therefore, such Classification can be utilized to reduce the volume and number of data transmissions through data aggregation. In this paper, we have shown formation of components and CH selection using VIC for given WMN.

The rest of the paper is organized as follows. Section 2 reviews the related work. General VIC method for Classification has been presented in Section 3. Section 4 describes the use of VIC for WMN. Section 5 concludes the paper.

2. Related Work

Classification in WMN is a process in which set of integrated information nodes are loosely connected and work together. All the nodes in the component elect one sub-region which is responsible for data aggregation and data transmission and maintaining connectivity between other sub-regions.

Brahim has suggested vector classification based on near optimal Classification in integrated information Network (SCNOPC-WMN) algorithm. This algorithm deals with the Classification problem in WMN. Resource aware adaptive Classification protocol is used for the bi-comparison vector classification and it guarantees robust Classification. SCNOPC-WMN also deals with the optimization of the resource dissipated in the network.

M. Chatterjee has proposed the weighted Classification algorithm (WCA) for ad hoc networks. WCA uses the on-demand Classification algorithm in multi hop radio networks. WCA elects the head nodes on the basis of neighboring nodes and their sending capabilities.

Banerjee has suggested hierarchical Classification algorithm based on geometric properties of the wireless network. Generic image algorithms developed for arbitrary images would not exploit the rich geometric information present in wireless network. Classification problem in an image is theoretical framework and presents an available distributed solution.

Adaptive Classification Protocol is proposed by S. Jin and M. Zhou [9]. It divides the network into several systematized hexangular and chooses the closest node to each hexangular as the head node for it. The nodes with the maximum amount of residual resource are selected as a sub-region.

Lu Dian et al. [10] proposed a Classification based spectrum allocation scheme for available spectrum allocation in cognitive radio networks. Vector image comparison theory is used to divide an image into components so that spectrum allocation is executed in parallel.

3. Component Handling using VIC

Vector image comparison technique uses information obtained from the characteristic values and characteristic vectors of their adjacency matrices for comparison of images. The methods are called vector, because they make use of the spectrum of the adjacency matrix of the data to component the points. Vector methods are widely used to compute image separation. Vector image comparison is a powerful technique in data analysis that has found increasing support and applications in many areas such as image segmentation and social network analysis. VIC divides the image into two disjoint groups, based on characteristic vectors corresponding to the second smallest characteristic value of the Kirchhoff's matrix.

Let $G(V,E)$ is an undirected image where V represents the set of vertices (nodes) and E represents the set of edges connecting these vertices. Each vertex is identified by an index $i \in \{1,2,\cdots,N\}$.

The edge between node i and node j is represented by e_{ij}. The image can be represented as an adjacency matrix. The adjacency matrix A of image G having N nodes is the N×N matrix where the non-diagonal entry a_{ij} is the number of edges from node i to node j, and the diagonal entry a_{ij} is the number of loops at node i. The adjacency matrix is symmetric for undirected images [8].

The adjacency matrix A is defined as

$$A=[a_{ij}]=\begin{cases}1 & edge\ weight\ \ betweennode\ i\ \ and\ node\ j\\ 0 & otherwise\end{cases}$$

We also define degree matrix D for image G. The degree matrix is a diagonal matrix which contains information about the degree of each node. It is used together with the adjacency matrix to construct the Kirchhoff's matrix of an image.

The degree matrix D for G is a N×N square matrix and is defined as

$$D=\left[deg_{ij}\right]=\begin{cases}total\ \ weight\ \ of\ \ edges\ \ incident\ \ to\ \ node\ \ i\\ 0.\end{cases}$$

The Kirchhoff's matrix is the combination of adjacency matrix and the degree matrix. The Kirchhoff's matrix of the image G having N vertices is N×N square matrix and is represented as

$$L=(D-A)+\frac{1}{N}$$

The normalized form of Kirchhoff's matrix can be written as

$$\gamma(i,j)=\begin{cases}1 & if\ \ i=j\ \ and\ \ \ deg_j\neq 0\\ -\dfrac{1}{\sqrt{deg_i\ \ \ deg_j}}\dfrac{1}{N} & if\ node\ i\ and\ node\ j\ are\ adjacent\\ 0 & otherwise\end{cases}$$

The characteristic values of matrix γ are denoted by λ_i, i=1,2,…N such that $\lambda_1 \leq \lambda_2 \leq \ldots \leq \lambda_n$. Kirchhoff's matrix has the property $\gamma.X=\lambda.X$ where X is the characteristic vector of the matrix γ and λ is the characteristic value of the matrix γ. Kirchhoff's matrix plays important role in vector image theory. λ_1 represents the number of sub-images in the network. The second smallest characteristic value λ_2 is referred to the algebraic connectivity and its corresponding characteristic vector is usually referred to as the Fiedler Vector.

We choose the characteristic vector values corresponding to the second smallest characteristic value λ_2. Second highest characteristic value (λ_2) divides the image into two sub-images. G is divided into two sub-images G+ and G−, where G+ and G− are the set of vertices related to the new sub-images. G+ contains nodes corresponding to positive characteristic values and G− contains nodes corresponding to negative characteristic values. The set of vertices is defined by $N=N^+\bigcup N^-$ such that $N^+\bigcap N^-=\varnothing$, where $N=\left|G\right|$, $N^+=\left|G^+\right|$ and $N^-=\left|G^-\right|$.

Based on the above concept, in next section we have proposed a new approach to partition the WMN into the components.

4. Component Formation in WMN

Here we apply the VIC technique to partition the net-work. VIC has many advantages as compared to other Classification algorithms. While Classification, it results in few links to other components but intra-component communication is high. Each node is at one hop distance from other node within the component. If the image is to be partitioned into more than two sub-images, apply VIC technique recursively. High intra-component similarity between the nodes makes VIC technique a better option for data Classification.

In our proposed method, Classification of WMN has been done by applying Vector Image Comparison technique recursively. Each node sends short message to sink which contains the location information of the node. On the basis of this information, the sink constructs the adjacency matrix and degree matrix and then constructs the Kirchhoff's matrix. The characteristic vector corresponding to second smallest characteristic value (called Fiedler Vector) is used to partition the WMN. The location of each node may be found by GPS (Global Positioning System) or any other localization method.

4.1. Steps for Classification

Construct an image G for the given integrated information network.

• Construct the normalized Kirchhoff's matrix, defined as

$$\gamma(i,j)=\begin{cases}1 & if\ \ i=j\ \ and\ \ \ deg_j\neq 0\\ -\dfrac{1}{\sqrt{deg_i\ \ \ deg_j}}\dfrac{1}{N} & if\ node\ i\ and\ node\ j\ are\ adjacent\\ 0 & otherwise\end{cases},$$

where deg_i is the degree of node i.

Form the Kirchhoff's matrix γ of the image. Compute the characteristic values and characteristic vector of Kirchhoff's matrix.

• Select the second smallest characteristic value λ2 of Kirchhoff's matrix γ.

• Choose characteristic vector value corresponding to the characteristic value λ2.

• Divide the image G into two sub-images G+ and G−, where G+ contains nodes corresponding to positive characteristic values and G− contains nodes corresponding to negative characteristic values.

After the first iteration of above algorithm, the whole network is divided into two components based on the characteristic values of the nodes. Table 1 shows the two partitions/ components after first iteration component 1 contains all the nodes with positive characteristic vector values and another component 2 contains nodes having negative characteristic vector values. Component 1 has six nodes A, B, C, D, E, and G with positive values of characteristic vector. Component 2 has six nodes F, H, I, J, K and L that have negative characteristic vector values. These components are listed in Table 2.

Table 1. Characteristic vector table and classification of given network.

Node	Degree	Characteristic Value	Characteristic Vector
A	4	0	0.306
B	3	0.120	0.275
C	4	0.450	0.301
D	4	0.864	0.232
E	6	1.000	0.270
F	5	1.052	-0.007
G	3	1.250	0.020
H	3	1.302	-0.131
I	3	1.303	-0.302
J	3	1.462	-0.426
K	4	1.505	-0.427
L	2	1.672	-0.368

Table 2. Initial component for the network.

Component Number	Nodes	Characteristic Value
Component 1	A,B,C,D,E,G	Positive
Component 2	F,H,I,J,K,L	Negative

The larger component can be further divided into two different components by applying the algorithm recursively. This process continues until maximum intra-node distance within a component is less than $R/2\sqrt{2}$, where R is the transmission rang of the integrated information node. When intra-node distance within a component is less than $R/2\sqrt{2}$, two nodes in neighboring components can communicate in one hop.

It has been observed that both the components have higher intra-node distance than $R/2\sqrt{2}$, so apply the algorithm to both the components. After applying the algorithm component 1 is portioned into two different components.

4.2. Sub-region Election

The Classification algorithm divides the whole network into components. The next step is election of sub-region for each component. As per the property of VIC, the least characteristic vector value of node signifies that the node is well connected to the other nodes within the component as well as it is connected to component [10].

For initial sub-region election, we chose the least characteristic vector value among the nodes within component. Therefore, we compare the characteristic vector values of the component and choose the least characteristic vector node as a sub-region, i.e.

Sub-region=Least |Characteristic Vector|.

Threshold value (E_{th}). The present sub-region declares the election process by sending a message that contains its E_{res} to all the component members. The component member whose residual resource is greater than Eres responds to this message by sending the residual resource to the sub-region.

The new sub-region is elected based upon CH Candidacy Factor (CF) defined as

$$CF_i = \frac{E^i_{res}}{D_i}\frac{N-1}{N},$$

where E^i_{res} is the residual resource of node I; D_i is the distance between node i and current sub-region. If (x_{ch}, y_{ch}) and (x_i, y_i) are the location coordinates of current sub-region and node i, respectably, then

$$D_i = \sqrt{(x_{ch}-x_i)^2 + (y_{ch}-y_i)^2}$$

A node with highest value of CF is elected as next sub-region.

5. Conclusion

This paper has proposes an approach to deal with the Classification problem in a given wireless integrated information network. The proposed algorithm partitions the given WMN into components such that nodes in a component are highly correlated and intra-component association is minimized. In WMN where nearby nodes have common interest in terms of sensing, our proposed algorithm is more suitable. Further we define the algorithm for sub-region election and conversion. The given method can be used in WMN to prolong the network service time.

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