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Pankaj Kumar Sa · Sambit Bakshi
Ioannis K. Hatzilygeroudis
Manmath Narayan Sahoo *Editors*

Recent Findings in Intelligent Computing Techniques

Proceedings of the 5th ICACNI 2017, Volume 2

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Foreword

Message from the General Chairs Dr. Modi Chirag Navinchandra and Dr. Pankaj Kumar Sa

Welcome to the 5th International Conference on Advanced Computing, Networking, and Informatics. The conference is hosted by the Department of Computer Science and Engineering at National Institute of Technology Goa, India, and co-organized with Centre for Computer Vision & Pattern Recognition, National Institute of Technology Rourkela, India. For this fifth event, held on June 1–3, 2017, the theme is security and privacy, which is a highly focused research area in different domains.

Having selected 185 articles from more than 500 submissions, we are glad to have the proceedings of the conference published in the *Advances in Intelligent Systems and Computing* series of Springer. We would like to acknowledge the special contribution of Prof. Udaykumar R. Yaragatti, Former Director of NIT Goa, as the chief patron for this conference.

We would like to acknowledge the support from our esteemed keynote speakers, delivering keynotes titled "*On Secret Sharing*" by Prof. Bimal Kumar Roy, Indian Statistical Institute, Kolkata, India; "*Security Issues of Software Defined Networks*" by Prof. Manoj Singh Gaur, Malaviya National Institute of Technology, Jaipur; "*Trust aware Cloud (Computing) Services*" by Prof. K. Chandrasekaran, National Institute of Technology Karnataka, Surathkal, India; and "*Self Driving Cars*" by Prof. Dhiren R. Patel, Director, VJTI, Mumbai, India. They are all highly accomplished researchers and practitioners, and we are very grateful for their time and participation.

We are grateful to advisory board members Prof. Audun Josang from Oslo University, Norway; Prof. Greg Gogolin from Ferris State University, USA; Prof. Ljiljana Brankovic from The University of Newcastle, Australia; Prof. Maode Ma, FIET, SMIEEE from Nanyang Technological University, Singapore; Prof. Rajarajan Muttukrishnan from City, University of London, UK; and Prof. Sanjeevikumar Padmanaban, SMIEEE from University of Johannesburg, South

Africa. We are thankful to technical program committee members from various countries, who have helped us to make a smooth decision of selecting best quality papers. The diversity of countries involved indicates the broad support that ICACNI 2017 has received. A number of important awards will be distributed at this year's event, including Best Paper Awards, Best Student Paper Award, Student Travel Award, and a Distinguished Women Researcher Award.

We would like to thank all of the authors and contributors for their hard work. We would especially like to thank the faculty and staff of National Institute of Technology Goa and National Institute of Technology Rourkela for giving us their constant support. We extend our heartiest thanks to Dr. Sambit Bakshi (Organizing Co-Chair) and Dr. Manmath N. Sahoo (Program Co-Chair) for the smooth conduction of this conference. We would like to specially thank Dr. Pravati Swain (Organizing Co-Chair) from NIT Goa who has supported us to smoothly conduct this conference at NIT Goa.

But the success of this event is truly down to the local organizers, volunteers, local supporters, and various chairs who have done so much work to make this a great event.

We hope you will gain much from ICACNI 2017 and will plan to submit to and participate in the 6th ICACNI 2018.

Best wishes,

Goa, India
Rourkela, India

Dr. Modi Chirag Navinchandra
Dr. Pankaj Kumar Sa
General Chairs, 5th ICACNI 2017

Preface

It is indeed a pleasure to receive an overwhelming response from academicians and researchers of premier institutes and organizations of the country and abroad for participating in the 5th International Conference on Advanced Computing, Networking, and Informatics (ICACNI 2017), which makes us feel that our endeavor is successful. The conference organized by the Department of Computer Science and Engineering, National Institute of Technology Goa, and Centre for Computer Vision & Pattern Recognition, National Institute of Technology Rourkela, during June 1–3, 2017, certainly marks a success toward bringing researchers, academicians, and practitioners in the same platform. We have received more than 600 articles and very stringently have selected through peer review 185 best articles for presentation and publication. We could not accommodate many promising works as we tried to ensure the highest quality. We are thankful to have the advice of dedicated academicians and experts from industry and the eminent academicians involved in providing technical comments and quality evaluation for organizing the conference in good shape. We thank all people participating and submitting their works and having continued interest in our conference for the fifth year. The articles presented in the three volumes of the proceedings discuss the cutting-edge technologies and recent advances in the domain of the conference.

We conclude with our heartiest thanks to everyone associated with the conference and seeking their support to organize the 6th ICACNI 2018 at National Institute of Technology Silchar, India, during June 4–6, 2018.

Rourkela, India	Pankaj Kumar Sa
Rourkela, India	Sambit Bakshi
Patras, Greece	Ioannis K. Hatzilygeroudis
Rourkela, India	Manmath Narayan Sahoo

In Memoriam: Prof. S. K. Jena (1954–2017)

A man is defined by the deeds he has done and the lives he has touched; he is defined by the people who have been inspired by his actions and the hurdles he has crossed. With his deeds and service, Late Prof. Sanjay Kumar Jena, Department of Computer Science and Engineering, has always remained an epitome of inspiration for many. Born in 1954, he breathed his last on May 17, 2017, due to cardiac arrest. He left for his heavenly abode with peace while on duty. He is survived by his loving wife, beloved son, and cherished daughter.

He is known for his ardent ways of problem-solving right from his early years. Even at 62 years of age, his enthusiasm and dedication took NIT Rourkela community by surprise. From being the Superintendent of S. S. Bhatnagar Hall of Residence to Dean of SRICCE to Head of the Computer Science Department to a second term as the Head of Training and Placement Cell, he not only has contributed to the growth of the institute, but has been a wonderful teacher and researcher guiding a generation of students and scholars. Despite this stature, he was an audience when it came to hearing out problems of students, colleagues, and subordinates, which took them by surprise being unbiased in judgments. His kind and compassionate behavior added splendidly to the beloved teacher who could be approached by all. His ideas and research standards shall continue to inspire generations of students to come. He will also be remembered by the teaching community for the approach and dedication he has gifted to the NIT community.

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About the Editors

Pankaj Kumar Sa received his Ph.D. degree in Computer Science in 2010. He is currently serving as an assistant professor in the Department of Computer Science and Engineering, National Institute of Technology Rourkela, India. His research interests include computer vision, biometrics, visual surveillance, and robotic perception. He has co-authored a number of research articles in various journals, conferences, and chapters. He has co-investigated some research and development projects that are funded by SERB, DRDOPXE, DeitY, and ISRO. He has received several prestigious awards and honors for his excellence in academics and research. Apart from research and teaching, he conceptualizes and engineers the process of institutional automation.

Sambit Bakshi is currently with Centre for Computer Vision & Pattern Recognition of National Institute of Technology Rourkela, India. He also serves as an assistant professor in the Department of Computer Science and Engineering of the institute. He earned his Ph.D. degree in Computer Science and Engineering. He serves as an associate editor of *International Journal of Biometrics* (2013–), *IEEE Access* (2016–), *Innovations in Systems and Software Engineering* (2016–), *Plos One* (2017–), and *Expert Systems* (2018–). He is a technical committee member of IEEE Computer Society Technical Committee on Pattern Analysis and Machine Intelligence. He received the prestigious Innovative Student Projects Award 2011 from the Indian National Academy of Engineering (INAE) for his master's thesis. He has more than 50 publications in journals, reports, and conferences.

Ioannis K. Hatzilygeroudis is an associate professor in the Department of Computer Engineering and Informatics, University of Patras, Greece. His research interests include knowledge representation (KR) with an emphasis on integrated KR languages/systems; knowledge-based systems, expert systems; theorem proving with an emphasis on classical methods; intelligent tutoring systems; intelligent e-learning; natural language generation; and Semantic Web. He has several papers published in journals, contributed books, and conference proceedings. He has over

25 years of teaching experience. He is an associate editor of *International Journal on AI Tools* (IJAIT), published by World Scientific Publishing Company, and also serving as an editorial board member to *International Journal of Hybrid Intelligent Systems* (IJHIS), IOS Press, and *International Journal of Web-Based Communities* (IJWBC), Inderscience Enterprises Ltd.

Manmath Narayan Sahoo is an assistant professor in the Department of Computer Science and Engineering, National Institute of Technology Rourkela, Rourkela, India. His research interest areas are fault-tolerant systems, operating systems, distributed computing, and networking. He is the member of IEEE, Computer Society of India, and The Institution of Engineers, India. He has published several papers in national and international journals.

Part I
Research on Optical Networks, Wireless Sensor Networks, VANETs, and MANETs

Multichannel Assignment Algorithm for Minimizing Imbalanced Channel Utilization in Wireless Sensor Networks

Abhinav Jain, Shivam Singh and Sanghita Bhattacharjee

Abstract Interference management is extremely important in wireless sensor networks (WSNs). Due to the sharing of spectrum, interference resulting from neighboring transmissions may degrade significantly the network performance. Use of multiple non-overlapping channels improves the network capacity or mitigates the interference by allowing multiple transmissions simultaneously on different channels. In this paper, we propose a centralized channel assignment method for single radio-equipped WSNs, which take advantage of multiple channels. The main objective is to minimize the imbalanced channel utilization among nodes in the network. Key components of the channel assignment procedure are root selection, node ordering, and channel selection. We divide the channel set of each node into three categories and assign channel to the node based on channel capacity, load of the node, and load of nodes in 2-hop local neighborhood. The simulation results demonstrate the effect of node ordering and root selection metrics on the network performance, in terms of channel utilization balancing and number of nodes accessing channel ratio.

Keywords Multichannel · Channel utilization balancing · Free channel
Primary channel · Secondary channel · Minimum assignable channel

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1 Introduction

In the past two decades, wireless sensor networks (WSNs) are popularly used as wireless technology for monitoring and controlling various real-time applications. The performance of WSNs is generally impaired by interference. High interference minimizes the overall network throughput and increases unnecessary energy consumption at the node. As a result, the power of a node depletes quickly and the network becomes partitioned. Therefore, interference reduction is an important issue in sensor network design. Transmission power control can minimize interference at the node. However, the power of a node affects the network connectivity as some links become inaccessible [1]. Multichannel technologies eliminate interference at node effectively and improve the overall capacity of the network by allowing concurrent transmissions on different channels. Although such schemes effectively improve the network performance, the number of channels is limited in wireless networks [2].

Researchers have proposed many multiple channel allocation algorithms [3–7] for wireless networks. However, these protocols are not suitable for WSNs because of the typical characteristics of the sensor. Generally, each sensor node is equipped with a single half-duplex radio [2], which cannot transmit and receive simultaneously, but can switch to different channels. MMSN [8] is a first single radio-based multichannel protocol for WSNs. In frequency assignment [8], frequency is assigned to each node for receiving the data, while in media access, the slot allocation is done for scheduling the nodes. In [9], the authors proposed routing-aware channels allocation algorithms for WSNs with an aim to minimize the maximum interference in the network. Hybrid-MAC (Hy-MAC) proposed in [10] utilizes multiple channels to get high throughput. An interference-aware MAC protocol (IM-MAC) for WSNs was introduced in [11]. IM-MAC improves the network throughput by minimizing the hidden terminal problem. In IM-MAC, channel assignment is done based on node ID, i.e., the node with the highest ID executes the channel allocation process. A game theory-based channel assignment protocol, known as ACBR, was proposed in [12] for prolonging the network lifetime. ACBR uses multiparameter-based utility function to choose a suitable channel for each node.

In this paper, we propose a multichannel assignment technique for WSNs, where each node is equipped with a single radio, which is capable of transmitting and receiving on a different channel. The goal of the work is to minimize imbalanced channel utilization among nodes, so that balanced channel utilization is achieved in the network. Our channel assignment scheme has three major components: (i) *root selection*, (ii) *node ordering,* and finally, (iii) *channel selection*. At first, root is selected and assigned the smallest numbered channel. Node ordering shows the order of assignment of nodes (except root), while in channel selection, each node selects its channel based on the channel capacity, traffic load of the node, and load of the nodes in 2-hop local neighborhood. The channel set of each node is divided into three categories: primary channel, secondary channel, and free channel. Free channels are interference free and are not chosen by the others in 2-hop local neighborhood. Primary channels can be used by 1-hop neighbors and might be assigned to the node if no free channel is available. Lastly, the secondary channels can be used by the interfering nodes and can be allocated only if no valid primary channel is available. Simulations are performed to evaluate the results that our scheme produces.

The rest of the paper is organized as follows: Sect. 2 describes the model and problem definition. The proposed multichannel assignment algorithm is described in Sect. 3, and results are discussed in Sect. 4. Finally, Sect. 5 concludes the paper.

2 Model and Problem Definition

2.1 Network Model and Assumptions

In this paper, wireless sensor network is represented as an undirected communication graph $G = (V, E)$ where V is set of static nodes and $E \subset V \times V$ is the set of edges. Each node is characterized by transmission range R_{max} and interference range I_{max} where $R_{max} \leq I_{max}$. Two nodes u and v are connected by an edge if they are 1-hop neighbors. Let, $N_1(u)$ be the set of 1-hop neighbors of node u. Any node $v \in N_1(u)$ if $d_{uv} \leq R_{max}$ where d_{uv} is Euclidian distance between nodes u and v. To find the interfering nodes of a node, we follow Protocol Interference Model [13]. Two nodes u and v will be interfering if they are operating in the same channel and $u \in N_2(v) \wedge v \in N_2(u)$ where $N_2(u)$ and $N_2(v)$ are the set of 2-hop neighbors of u and v, respectively. In this paper, we have made following assumptions:

- K: The set of different and non-overlapping channels in the network. The capacity of each channel is same, and it is denoted by CT_c where $c \in K$.
- C: A $1-D$ channel assignment array and is initialized to 0.
- $L(u)$: The traffic load of node u and it is known a priori.

2.2 Problem Definition

The objective of the channel assignment algorithm presented in this paper is to assign one of K channels to each node in such a way that minimizes imbalanced channel utilization among nodes in the network.

To maximize the channel utilization of node u, we define a binary channel assignment variable $C^c_{u,v}$ for each node $v \in N_2(u)$. Binary variable $C^c_{u,v}$ will be 1 if v is within 2-hop away and both u and v are operating on the same channel c.

$$C^c_{u,v} = \begin{cases} 1, & \text{if } v \in N_2(u) \wedge C(u) = C(v) = c \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

Now, we define the load on the channel of node u by

$$L_u(c) = \sum_{\substack{C(u)=C(v)=c \\ c \in K}}^{v \in N_2(u)} C^c_{u,v} \times L(v) + L(u) \tag{2}$$

Using Eq. (2), we calculate the channel utilization of node u and it is given as

$$Z_u(c) = \frac{CT_c}{L_u(c)} \tag{3}$$

We use standard deviation $(Z(G))$ given in Eq. (5) to calculate channel utilization balancing in G. Standard deviation is a metric that finds the deviation of channel utilization in G. Lower value implies better balancing. $\bar{Z}(V)$ is defined in Eq. (4).

$$\bar{Z}(V) = \sum_{c \in K}^{V} u = 1 Z_u(c) \tag{4}$$

$$Z(G) = \sqrt{\frac{1}{|V|} \sum_{u=1}^{V} \left(Z_u(c) - \bar{Z}(V)\right)^2} \tag{5}$$

Therefore, our channel assignment problem becomes

$$minimize(Z(G)) \tag{6}$$

Subject to: 1. $C(u) \in K, \forall u \in V$
2. $CT_c - C^c_{u,v} \times L(v) - L(u) > 0, \forall u \in V \& v \in N_2(u)$

3 Proposed Multichannel Assignment Algorithm

In this section, we present a centralized channel assignment algorithm which assigns a different channel to each node in WSNs. The key aim is to minimize imbalanced channel utilization among nodes. The proposed method has three phases, namely root selection, node ordering, and channel selection which are described subsequently.

3.1 Phase I: Root Selection

At first, we select the root and assign the smallest numbered channel to it. One way to select the root is lowest ID, i.e., the node with the smallest ID becomes the root. The next alternative to choose the root is maximum degree which includes both 1-hop and 2-hop neighbors. Another criterion is minimum degree, i.e., the node with the minimum degree is selected as the root for the channel assignment process.

3.2 Phase II: Node Ordering

The second important issue is node ordering which basically reflects the order in which the nodes are considered for channel assignment. Here, we discuss three ordering alternatives. First one is random ordering (RO) which uses randomization to organize the nodes (except the root) for channel assignment. The next alternative uses some fixed order (FO) to arrange the nodes. The channel assignment with random and fixed ordering of nodes is given in Algorithm 1 and Algorithm 2, respectively. Another alternative that we consider is minimum assignable channel (MAC)-based node ordering. Previous two techniques (i.e., RO and FO) use the original graph G to order the nodes, while MAC-based technique utilizes the interference graph, denoted by G^2, for organizing the nodes for the channel allocation. Interference graph G^2 consists of V nodes and E^2 edges. Two nodes u and v are connected by an edge, i.e., $(u, v) \in E^2$ if $u \in N_2(v) \wedge v \in N_2(u)$. In MAC-based ordering, we use *BFS*-based traversal to traverse all nodes in G^2 and then assign labels to them. Here, the root is initialized to level 0. MAC generally works in top to bottom fashion, i.e., nodes in lower level get their channels earlier than upper layer. In each layer, we calculate the number of free channels (FCs) for each node and select the node with the minimum value for channel allocation. If a tie happens, the node ID is used to break it. The channel assignment when MAC-based ordering is used is briefly shown in Algorithm 3.

Algorithm 1: RO-based Channel Assignment

```
C(v) ≔ 0, ∀v ∈ V
root ≔ Root Selection(V)
C(root) ≔ Channel Selection(root, K)
Permutate(V\{root})
while (V! = Empty)
        v ≔ Removehead(V)
        C(v) ≔Channel Selection(v, K)
        V ≔ V−1
end while
return(C)
```

Algorithm 2: FO-based Channel Assignment

```
C(v) ≔ 0, ∀v ∈ V
root ≔ Root Selection(V)
C(root) ≔ Channel Selection(root, K)
U ≔ { }
for i: = 0 to |V| − 2 do
      U ≔ U ∪ { (root + i)mod V + 1}
end for
while (U! = Empty)
        v ≔ Removehead(U)
        C(v) ≔ Channel Selection(v, K)
    U ≔ U−1
end while
return(C)
```

3.3 Phase III: Channel Selection

The goal of this phase is to assign a different channel to each node in the network. Similar to [11], the entire channel set of a node is divided into three categories: Free channel set (FCS), primary channel set (PCS), and secondary channel set (SCS).

FCS of node u, $FCS(u)$, contains set of channels which are not assigned in u's neighborhood. If $FCS(u)$ is available, u selects the smallest numbered channel. *PCS* of node u, $PCS(u)$, is a set of channels which are used by 1-hop neighbors of u. If $FCS(u)$ is empty, then u can choose its channel from $PCS(u)$ only if it has valid channel. A channel is said to be valid if the current capacity of the channel is greater than the load of the node where the current capacity is complementary of total capacity and load of neighbor nodes using that channel. If more than one channel is available, the channel with the least load is selected. Node u can select the secondary channel only if *PCS* is empty. The secondary channel set contains the channels which are used by 2-hop neighbors of the node. If valid secondary channels are available, node u chooses the least loaded channel. Since $SCS(u)$ is *PCS* of $N_1(u)$, node u discards those primary channels which are in $SCS(u)$. After selection, node u broadcasts the assigned channel and ID within its 2-hop local neighborhood. All nodes in the neighborhood update their primary, secondary, and free channel set accordingly. Algorithm 4 describes our channel assign method in brief.

Algorithm 3: MAC-based Channel Assignment

$C(v) \coloneqq 0,\ \forall v \in V$
$root \coloneqq$ Root Selection(V)
Build Interference Graph $G^2(V, E^2)$ from $G(V, E)$
$level(root) \coloneqq 0$
$LS \coloneqq$ LevelStructure$(G^2, root)$
$C(root) \coloneqq$ Channel Selection$(root, K)$
for each $l \in LS$ **do**
    $nodeset \coloneqq \{v \mid level(v) == l \;\&\; C(v) = 0\}$
while $(nodeset\, != Empty)$
        $v \coloneqq arg\, min_{v \in V} |FCS(v)|$
        $C(v) \coloneqq$ Channel Selection(v, K)
    $nodeset \coloneqq nodeset - 1$
    end while
end for
return(C)

Algorithm 4: Channel Selection

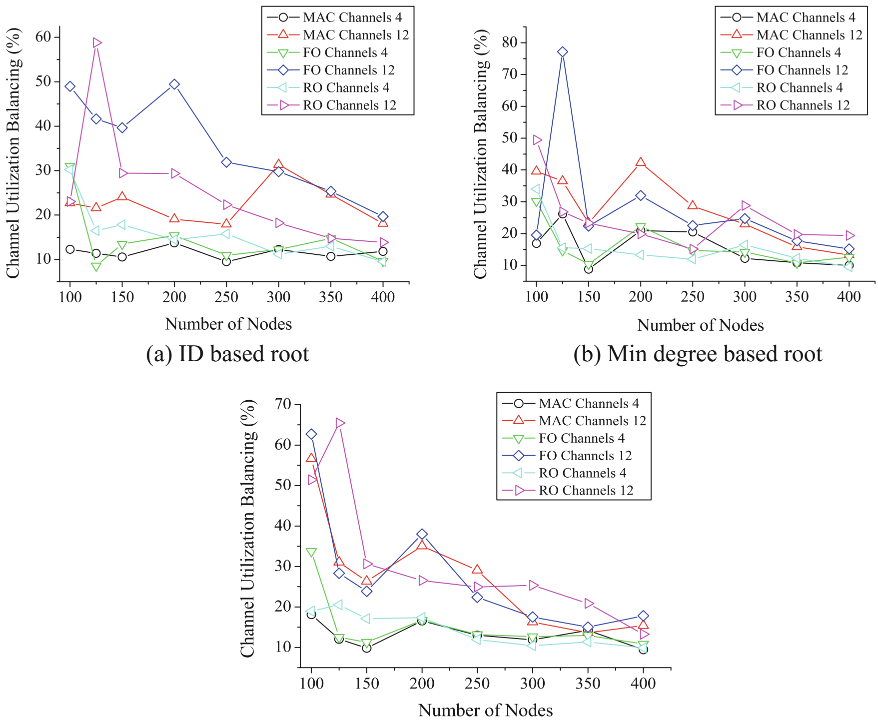
```
Get FCS, PCS and SCS for node v
if (FCS(v) != Empty)
    c := Findsmallestnumberchannel(FCS)
    C(v) := c
end if
if (FCS == Empty & PCS != Empty)
    for each channel c ∈ PCS(v) do
        if (channel c ∈ SCS(v)) | (CT_c − Σ_{u∈N_1(v), C(u)=c} L(u) < L(v))
            remove c from PCS(v)
            continue
        end if
    end for
c := Findleastloadedchannel(PCS)
C(v) := c
end if
if(PCS == Empty & SCS != Empty)
    for each channel c ∈ PCS(v) do
        if(CT_c − Σ_{u∈N_2(v), C(u)=c} L(u) < L(v))
            remove c from SCS(v)
            continue
        end if
    end for
c := Findleastloadedchannel(SCS)
C(v) := c
end if
Node v broadcasts <c,ID> in its local neighborhood
N_1(v) updates FCS and PCS; N_2(v) updates FCS and SCS
return(c)
```

4 Results and Discussion

In this section, we conduct simulations to evaluate RO-, FO-, and MAC-based channel assignment approaches and then compare their performances with respect to channel utilization balancing and number of nodes accessing channel ratio. All algorithms are simulated through MATLAB and C programming language. We consider $1000 \times 1000\,\text{m}^2$ square field where sensor nodes are randomly distributed. Number of nodes, $|V|$, varies from 100 to 400. Transmission range of each node is 50 m, and interference range is 100 m. The number of available channels is 4 and 12. The channel is assumed to be error-free, and capacity of each channel is set to 10 Mz. Load at each node is assigned randomly in the range of [0.1–1.0].

Figure 1 shows the performance of channel utilization balancing for RO-, FO-, and MAC-based channel assignment approaches for 100–400 nodes but for different number of channels. It is clear that the channel utilization decreases as number of nodes increases. The increasing network size brings more interference at node and degrades the performance of the network. We have also seen that balancing value is much higher using 12 channels. Increased number of channels not only minimizes number of conflicting nodes, but also reduces load on channels. As a result, channel utilization balancing is increased.

Figure 1a depicts the performance of channel utilization balancing when the root is the smallest ID node. MAC-based channel assignment achieves better channel utilization than RO and FO. In MAC, the node is selected based on its free channels and thereby minimizes imbalanced channel utilization. From Fig. 1a, it is clear that



(a) ID based root

(b) Min degree based root

(c) Max degree based root

Fig. 1 Comparing MAC, FO, and RO in terms of channel utilization balancing