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Weighted Majority Game-based Femtocell Selection and Beam Allocation for 5G-IoT

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Abstract

This article proposes a weighted majority game based femtocell selection and beams allocation approach for the 5G-IoT network. This approach is for the indoor region as small cell base station is considered. Here Multiple Input Multiple Output (MIMO) base station is the primary base station under which femtocells are deployed. MIMO with spatial modulation transmits the signal to the femtocell. Multiple IoT devices are connected with femtocell and share the same communication resources. Beamforming allows a proficient organization of intercell interference for short-distance data transmission. Weighted majority co-operative game based femtocell selection and beam allocation strategy is proposed here. The performance of the proposed approach is measured by simulation results which illustrates that the proposed architecture diminishes power consumption by 10-15%. Comparative analysis with existing approaches shows that it is a novel and green approach.

1 Introduction

In the area of advanced mobile communication, energy efficiency, and spectral efficiency are leading issues for 5G wireless communications [1]. 5G mobile network is going through some severe challenges, such as the need for one million connections per kilometer square area and user connectivity in the Gbps data rate to meet the demand of the end-users [2]. IoT environment is nowadays totally based on 5G mobile network, as massive connectivity is the prime requirement of IoT [3]. It is predicted that in 2020 approximately 11.8 billion mobile devices would be connected to the internet through a 5G wireless network, and more than 8.2% of devices will be low power generated smart IoT devices. Most of the IoT environment is indoor region-based [4]. Energy consumption in the wireless industry is increasing rapidly. Green communication in indoor and outdoor heterogeneous networks is on demand. [5-6]. Thus beamforming technology of the 5G network supports massive connectivity with high spectral efficiency for the indoor IoT paradigm [7-8]. The indoor region needs small cells [9] like indoor femtocell deployment to maintain efficient connectivity [10]. Femtocell is a low power home base station.

One of the challenging issues in 5G based IoT network is to connect a massive number of devices with the proper spectrum. To connect more devices, effective spectrum allocation is required. Frequencies are in underutilized scenario due to interference in the network and also lack of adequate utilization of spectrums [11]. That increases the massive power consumption of the network. In the fifth-generation (5G) network, different technologies can be used to overcome the above crisis. Beamforming is one of them [12].

MIMO in the 5G wireless network gives advantages in power and spectrum optimization [13]. Though massive connectivity is the prime concern, it creates network densification. Deployment of a vast number of small cells produces interference, which reduces the QoS of the network.

Motivated by the above circumstances, we have proposed an algorithm to select femtocell and allocate the proper beam to the indoor IoT devices using game theory [14].

In this article femtocell selection and beam allocation to the IoT devices of an indoor region based on weighted majority game is proposed.

IoT devices register under femtocell base station. If no IoT device registers under a femtocell, that femtocell switches to deactivate mode hence reduces power consumption. Based on the payoff matrix of the weighted majority game [15] femtocell is selected. The parameters for the payoff matrix are load and distance. These parameters decide the weight of each femtocell. Using this approach power consumption of the network reduces.

Section 2 of this article describes the algorithm and describes the proposed approach. The mathematical explanation is given in section 3. The result and comparison of the proposed approach are illustrated in section 4. Section 5 concludes the article.

2 Proposed Weighted Majority Game-based Femtocell Selection and Beam Allocation

In the proposed approach IoT devices are located in an indoor region under the coverage area of a small cell base station femtocell. Femtocell is placed under a MIMO base station and hence form a two-tier network. In this proposed approach beamforming technique is considered with the presence of channel uncertainty condition [16]. We have adopted here beamforming codebook restriction approach. This approach enables IoT devices registered under the femtocell to choose the best channel or beam using weighted majority game. Femtocells are selected and Beams are allocated to the IoT devices using weighted majority game.

Weighted majority co-operative game incorporates two positive integer values as parameters. They are i) weight and ii) quota. In our femtocell selection and beam allocation approach, the number of IoT devices registered under a femtocell represents weight. And the distance between IoT devices and femtocell denotes quota. Algorithm 1 depicts the proposed approach. The high majority of femtocells are chosen depending on the two parameters.

The proposed weighted majority game based femtocell selection and beam allocation approach are shown in Figure 1. The architecture of the proposed approach is shown in Figure 1. (a). Here IoT devices are registered under a home base station femtocell and femtocell is deployed under the coverage area of a MIMO base station. Femtocell allocates beam to IoT devices. In Figure 1. (b) femtocell selection and beam allocation takes place. The payoff matrix shows the load and distance values for IoT device 4 from femtocell 1 and femtocell 2 respectively. Femtocell 1 and Femtocell 2 have the same load but the distance between the IoT device and Femtocell 2 is minimum so Femtocell 2 is selected for allocating the beam to IoT device 4.

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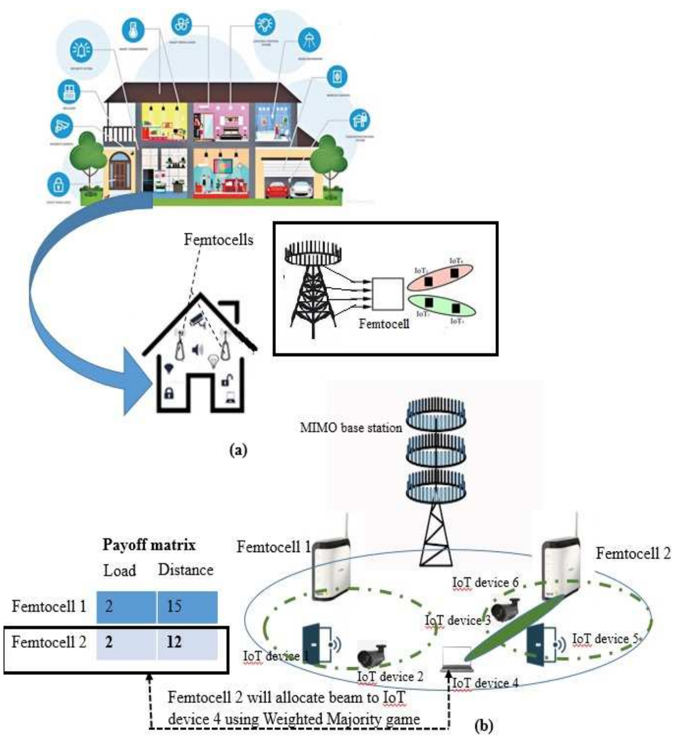

Figure 1. (a) Proposed architecture
(b) Femtocell is selected and allocation of beam takes place based on weighted majority game.

Algorithm 1 describes the working process of the proposed approach

Algorithm 1. Weighted Majority Game-based Femtocell Selection and Beam Allocation for 5G-IoT

Inputs: • Load of each Femtocell.
• Minimum distance (quota) of each femtocell from IoT devices.
Output: Selection of Femtocell.

1. **Start**
2. Initialize the maximum load of each femtocell
3. Calculate load or weight of the femtocell
4. **For** k=1: N_s femtocells
6. **If** the distance between IoT device and femtocell k is minimum
7. The femtocell is selected. And the femtocell allocates beam to the IoT device
8. **Else If**
9. Find another femtocell
10. **End If**
11. **If** there is no IoT device inside femtocell k,
12. The femtocell k goes to switched off mode
13. **End If**
14. **If** IoT devices come under femtocell k which is in sleep mode,
15. The femtocell k becomes activated
16. **End If**
17. **End for**
18. **End**

3 Mathematical Description

In the proposed weighted majority game based femtocell selection and beam allocation approach femtocell F_{high_weight} is selected based on the load of femtocell and minimum distance from the IoT devices.

$$F_{high\_weight} = F_{\min\_dis} \cap F_{load}$$

The parameters used in calculating the power consumption of the proposed approach are presented in Table 1.

Table 1. Parameters for mathematical description

Parameters	Description
PT_{TIoT}	The transmission power of each IoT device
P_{MIMO}	Transmission power by per antennas in MIMO base station
P_{femto}	Transmission power by per femtocell base station
ρ	Static circuit transmission power
σ	Gaussian noise
P_f	Minimum received power by IoT device
g_f	Antenna gain of femtocell

4.1. Power transmission model

The total transmitted power of the proposed IoT architecture is

$$P_{WPT} = P_{IoT} + P_{Cercuit} \quad (1)$$

Specifically, P_{IoT} is the transmission power for all IoT devices

$$P_{IoT} = \sum_{i=1}^{n} PT_{TIoT} \quad (2)$$

Where $\boldsymbol{PT_{TIoT}}$ denotes the transmission power by each IoT devices and the total n number of devices are considered in the network

$P_{circuit}$ denotes circuit transmission power in the processing unit both the transmitter and receiver

$$P_{circuit} = A * P_{MIMO} + B * P_{femto} + \rho + \sigma \quad (3)$$

where, P_{femto} is the transmission power by each femtocell. The transmission power of femtocell is denoted as:

$$P_{femto} = \frac{P_f 4\pi}{(3\sqrt{3/2})Dg_f} \quad (4)$$

4 Results and Discussions

4.1 Power Consumption

The power transmitted by femtocells in the proposed network is presented in Figure.2. The result of the proposed approach is compared with the conventional heterogeneous IoT network. Figure.2 shows that the proposed approach is approximately 10-15% power-efficient than a conventional heterogeneous IoT network. For simulation purposes, we have assumed the total number of antennas in the MIMO base station is 250. Transmission power by each antenna of MIMO base station P_{MIMO} is 0.2 watt. Transmission power by each IoT device is 0.005watt. Transmission power by indoor femtocell is 0.063 watt. Transmitter antenna gain of MIMO and femtocell are 0.005 and 0.001 respectively.

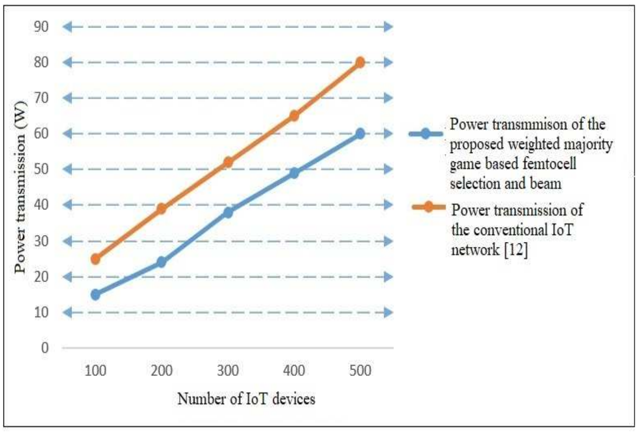

Figure.2. Comparison of power transmission between proposed and existing IoT approaches

4.2 Comparison with the existing approaches

Table 2 describes the comparison between the proposed and existing IoT approaches.

Table 2. Comparisons with the existing approaches

Properties	Working principle	Consideration of Indoor region	Reduction in power consumption
Energy-Efficient IoT network for femtocell based Network [9]	Small cell cellular network	✓	-
User Scheduling and Power Allocation for Massive IoT Devices [14]	MIMO based mobile network	-	-
Energy-Efficient IoT peer to peer [12]	Conventional IoT network	-	10-15%
Proposed femtocell selection and beam allocation for IoT network	Weighted majority game based femtocell selection and beam allocation for Indoor 5G Network	✓	-

5 Conclusion

This article proposes a power-efficient femtocell selection and beams allocation approach for an indoor IoT environment to serve various users based on a 5G network. The usage of widespread beamforming allows efficient management of intercell interference. Here MIMO with spatial modulation base station is considered as the main base station for its massive connectivity. MIMO transmits the signal to the indoor femtocell. Multiple IoT devices are connected with those femtocells. An algorithm has been discussed in this article to select the femtocell using weighted majority game. Simulation results show that the proposed network has validated the effectiveness by reducing power consumption. Thus it is concluded that the proposed strategy is a power-efficient approach for 5G-IoT.

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7 References

1. M. Shafi, A. F Molisch, P. J. Smith, T. Haustein, P. Zhu, P. De Silva, and G. Wunder, "5G: A tutorial overview of standards, trials, challenges, deployment, and practice," *IEEE journal on selected areas in communications*, **35**, 6, Apr. 2017, pp., doi: 1201-1221. 10.1109/JSAC.2017.2692307

2. J. Lee, E. Tejedor, K. Ranta-aho, H. Wang, K. T. Lee, E. Semaan, and S. Jung, "Spectrum for 5G: Global status, challenges, and enabling technologies," *IEEE Communications Magazine*, **28**, 3, Mar. 2018, pp. 12-18, doi: 10.1109/MCOM.2018.1700818

3. A. Al-Fuqaha, M. Guizani, M., Mohammadi, M. Aledhari, and M. Ayyash, "Internet of Things: A survey on enabling technologies, protocols, and applications," *IEEE Communications Surveys & Tutorials*, **17**, 4, Jun. 2015 pp. 2347-2376, doi: 10.1109/COMST.2015.2444095

4. G. Oguntala, R. Abd-Alhameed, S. Jones, J. Noras, M. Patwary, and J. Rodriguez, "Indoor location identification technologies for real-time IoT-based applications: An inclusive survey," *Computer Science Review*, **201830**, Feb. 2020, pp.55-79, doi: 10.1016/j.cosrev.2018.09.001

5. R. Ruby, S. Zhong, D. W. K., Ng, K. Wu, and V. C. Leung, "Enhanced energy-efficient downlink resource allocation in green non-orthogonal multiple access systems," *Computer Communications*, **139**, May. 2019, pp. 78-90, doi: 10.1016/j.comcom.2019.03.010

6. Z. Du, "Energy analysis of Internet of things data mining algorithm for smart green communication networks," *Computer Communications*, Feb. 2020, **152**, pp. 223-231, doi: 10.1016/j.comcom.2020.01.046

7. B. Li, Z. Fei, and Z. Chu, "Optimal transmit beamforming for secure SWIPT in a two-tier HetNet," *IEEE Communications Letters*, **21**, 11, Aug. 2017, pp. 2476-2479, doi: 10.1109/LCOMM.2017.2734759

8. F. Alavi, K. Cumanan, Z. Ding, and A. G. Burr, "Beamforming techniques for nonorthogonal multiple access in 5G cellular networks," *IEEE Transactions on Vehicular Technology*, 2018, **67**, 10, July. 2018, pp. 9474-9487, doi: 10.1109/TVT.2018.2856375

9. A. Mukherjee, S. Bhattacherjee, S. Pal, and D. De, "Femtocell based green power consumption methods for mobile network. *Computer Networks*, **57**, 1, Jan. 2013, pp. 162-178, doi: 10.1016/j.comnet.2012.09.007

10. X. Huang, S. Tang, Q. Zheng, D. Zhang, and Q. Chen, "Dynamic Femtocell eNB On/Off Strategies and Seamless Dual Connectivity in 5G Heterogeneous Cellular Networks," *IEEE Access*, **6**, Jan. 2018, pp. 21359-21368, doi: 10.1109/ACCESS.2018.2796126

11. B. Soret, A. De Domenico, S. Bazzi, N.H. Mahmood, and K. I. Pedersen, "Interference coordination for 5G new radio," *IEEE Wireless Communications*, Nov. 2017, **25**, 3, pp. 131-137, doi: 10.1109/MWC.2017.1600441

12. Z. T. Al-Azez, A. Q. Lawey, T. E. El-Gorashi, and J. M. Elmirghani, "Energy efficient IoT virtualization framework with peer to peer networking and processing," *IEEE Access*, **7**, Apr. 2019, pp. 50697-50709, doi: 10.1109/ACCESS.2019.2911117

13. L. D. Nguyen, H. D. Tuan, T. Q. Duong, O. A. Dobre, and H. V. Poor, "Downlink Beamforming for Energy-Efficient Heterogeneous Networks With Massive MIMO and Small Cells," *IEEE Transactions on Wireless Communications*, **17**, 5, Mar. 2018 pp. 3386-3400, doi: 10.1109/TWC.2018.2811472

14. M. A. Almagboul, F. Shu, Y. Qin, X. Zhou, J. Wang, Y. Qian, and K. J. Zou, "An Efficient Hybrid Beamforming Design for Massive MIMO Receive Systems via SINR Maximization Based on an Improved Bat Algorithm," arXiv preprint arXiv:1811.01176, Nov. 2018, doi: 10.1109/ACCESS.2019.2942350

15. N. Li, J. F. Martinez-Ortega, and V. H. Diaz, "Distributed power control for interference-aware multi-user mobile edge computing: a game theory approach," *IEEE Access*, **6**, Jun. 2018, pp. 36105-36114, doi: 10.1109/ACCESS.2018.2849207

16. A. Mukherjee, P. Deb, D. De, and M. S. Obaidat, "WmA-MiFN: A weighted majority and auction game based green ultra-dense micro-femtocell network system," *IEEE Systems Journal*, **14**, 1, May, 2019 pp. 353-362, doi: 10.1109/JSYST.2019.2911977

17. K. S. Mohamed, M. Y. Alias, and M. Roslee, "Interference management using beamforming techniques for line-of-sight femtocell networks," *IEICE Transactions on Communications*, **103**, 8, Aug. 2020, pp. 881-887, doi: 10.1587/transcom.2019EBP3172