International Journal of Engineering & Technology, 8 (1.9) (2019) 668-672

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Path Life Based on SNR Modeling for Routing Protocol Improvement with Cross Layer Scheme in Wireless Adhoc Network

Istikmal1[*2], Adit Kurniawan[1], and Hendrawan[1]

[1]*School of Electrical Engineering and Informatics, Institut Teknologi Bandung, Indonesia.*
[2]*Faculty of Electrical Engineering, Telkom University, Bandung, Indonesia*
**Corresponding author E-mail: erna@fis.uin-malang.ac.id*

Abstract

In this paper, we develop a detailed approach modeling to study how channel quality, as represented by the Signal-to-Noise Ratio (SNR), impacts on the path life of the route and the network throughput performance. Based on this fact, we proposed an adaptive algorithm for routing protocol with a cross-layer scheme based on SNR. This proposed scheme is an enhancement of reactive routing protocol Ad-hoc On-demand Distance Vector (AODV), which we call AODV SNR+. We use a combination of the preset SNR threshold and the minimum SNR threshold in the route discovery process. With this combined scheme, the routing protocol can select an appropriate route with quality channel aware and be more adaptive when path break often occur in the network. We compare AODV SNR+ with AODV and AODV SNR-SR (Selective Route). The simulation results showed that AODV SNR+ outperform AODV. We found that AODV SNR+ suitable in dynamic networks, while AODV SNR-SR can gain advantage in high traffic with stable channel quality.

Keywords*: Path life, Routing, SNR, AODV, Cross-Layer*

1. Introduction

In the future, routing protocol will play more important role in device-to-device (D2D) and machine-to-machine (M2M) communication, as one of the key technologies of 5G (S. Mumtaz et al, 2014). Recently, availability and quality became an important research in the routing protocol. One of the promising methods to solve these problems is a cross-layer approach, which is divided based on the general and specific solutions (R. Edirisinghe et al, 2014). In principle, they are two basic parameters of routing quality, i.e. based on service quality and based on channel quality. Researchers have proposed service quality aware routings, such as effective estimated throughput as a metric to find the best path (K. Kunavut, 2013), expected transmission count (D. De Counto et al, 2003), expected transmission time (R. Draves et al, 2004), and medium time metric (B. Awerbuch et al, 2006). Other proposals for quality of channel aware include using receive power to find the chosen path (Fuad A., 2011), improving multi-hop routing with signal-to-noise ratio (R. Aguero et al, 2009; B. Amiri et al, 2011), routing metric using average weight SNR (M. Elshaikh et al, 2012), and routing metric using expected path bandwidth (Xiaoheng D. et al, 2013).
In this paper, we proposed an enhanced version of AODV (C.E.Perkins et al, 1999) based on SNR, with cross-layer scheme, which we call AODV SNR+. The important aspect of this enhancement unaddressed in previous work, is that we combine SNR threshold and minimum SNR threshold in the route discovery process. This combination is used for adaptive routing in AODV SNR+ when Route Error (RERR) occurs. With this algorithm, the average path life of the route can be improved when the path breaks often occur. To give more explanation, we developed path life modeling based on SNR to show the correlation between the throughput performance with path life and channel quality.

2. Methods

Throughput and path life model

We build throughput modeling with correlation between path life and the SNR of the link. Intuitively, the throughput performance will depend on how long the path establishes to deliver the data from source to destination. Another study (Fan Bai *et al*, 2004) has used path duration model, but in different routing protocol and scope. We develop a model of the AODV routing protocol with path life as shown in Figure 1.

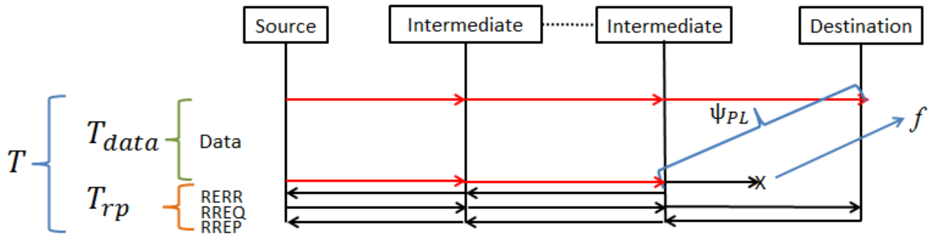

Fig. 1: The model of routing protocol AODV with path life.

The total time of the simulation is T, and actual data transfer time at the maximum rate is T_{data}. Due to mobility and weakened signal, the link breaks often occur in the path. The intermediate node will generate a RERR notification to the source, and enter a route discovery process by broadcasting the route request (RREQ) when the source does not have an alternative route. After RREQ arrives at destination, route reply (RREP) is generated and sent to the source. If the total time needed to repair broken path is T_{rp}, while the total time spent to repair a broken path each time is t_{rp}, and f as the frequency of path breaks, then we can write the relation between T, T_{data}, and T_{rp} as

$$T = T_{data} + T_{rp}. \quad [1]$$

Because the total time required to repair broken path is affected by total frequency of path break, where $T_{rp} = f t_{rp}$, then we can find the time used to transfer data as $T_{data} = T - (f\, t_{rp})$. If K is total data transferred during simulation, then throughput B is given by

$$B = \frac{K}{T_{data} + (f\, t_{rp})}, \quad [2]$$

For each source to destination pair, the data rate R is K/T_{data}. Hence, from [1] and [2], we can write

$$B = \frac{K}{T_{data}}\left(\frac{T - (f\, t_{rp})}{T}\right) = \left(1 - \frac{f\, t_{rp}}{T}\right)R. \quad [3]$$

If the average path life of transmission line formed in data transmission is ψ_{PL}, then we can express $\psi_{PL} = T/f$, so we can rewrite [3] as

$$B = \left(1 - \frac{t_{rp}}{\psi_{PL}}\right)R. \quad [4]$$

Link life and link availability based on channel quality

Path life depends on link life based on quality of link connection. If there is a broken link, then the formation of the path also ends. To understand the correlation between path life and quality of link in terms of SNR, we used mobility and connection models. Our model is developed from the prediction-based link availability estimation (Shengming J, 2005). In this study, two mobile Nodes 1 and Node 2 move along solid line during a random time interval with the angle φ, and nodes speeds are v_1 and v_2. In this model the SNR values have deterministic approach, where $SNR = 10 \log P_r/N$, with receive signal strength is P_r and assume noise value (N) is constant and equal on all the nodes. If i represents nodes position between Node 1 and Node 2 in time i from the first time connection, t_0, to the last time position T_i, then $t_i = t_0 + T_i$. If SNR is proportional to square of the distance, then we can calculate the SNR in time i (SNR_i) as

$$SNR_i = (a + v_1 T_i)^2 + (b + v_2 T_i)^2 - 2\,(a + v_1 T_i)(b + v_2 T_i)\cos\varphi\,, \quad [5]$$

if values of v_1, v_2, a, b, and φ are constant against T_i during time T, and the change rate of those values are constant, where $\partial^2 SNR_i/\partial^2 T_i = 0$, then we can simplify [5] as

$$SNR_i = \lambda T_i^2 + \alpha\, T_i + \beta. \quad [6]$$

Using [6], we can find SNR_i between Node 1 and Node 2 at $t_i = t_0 + T_i$. For $t_0 = 0$, the value of $SNR_0 = \beta$. After finding SNR_0, the value of λ and α can be calculated by

$$\lambda = \frac{(SNR_1\, t_2 - SNR_2\, t_1) - SNR_0(t_2 - t_1)}{t_2 t_1^2 - t_1 t_2^2}, \quad [7]$$

$$\alpha = \frac{(SNR_1\, t_2^2 - SNR_2\, t_1^2) - SNR_0(t_2^2 - t_1^2)}{t_1 t_2^2 - t_2 t_1^2}. \quad [8]$$

Now we can find the value of SNR_i for $t_i \leq T$. If t_R is the last time a link has been connected at SNR_R, where $t_R = t_0 + T_R$ and $t_0 = 0$, then we can calculate t_R from [6] as

$$t_R = \frac{\sqrt{\alpha^2 + 4\,\lambda\, SNR_R - 4\,\lambda\,\beta} - \alpha}{2\,\lambda}, \quad [9]$$

next we can calculate the time of link life as $T_{Link\ Life}$ in a connection. If a connection is established, and the last time of a connected link is t_R, then we can find the link life of connection from time t_1 by $T_{Link\ Life}(t_1, t_R) = t_R - t_1$. We can calculate the quality of link connection, Q_{link}, from the trend of SNR value for the first time t_i connecting until the last time of connection t_R, as $Q_{link}(t_i, t_R) = (SNR_i, t_i) - (SNR_R, t_R)$. The link quality will get optimal when the link connection has maximum SNR, which is $Q_{link-max}(t_i, t_R)$. While in time T the connection will have average link quality, $Q_{link-avr}(t_i, t_R)$. Statistically, the link quality estimation can be measured by

$$Q_{link} = \frac{Q_{link-avr}(t_i, t_R)}{Q_{link-max}(t_i, t_R)}, \quad [10]$$

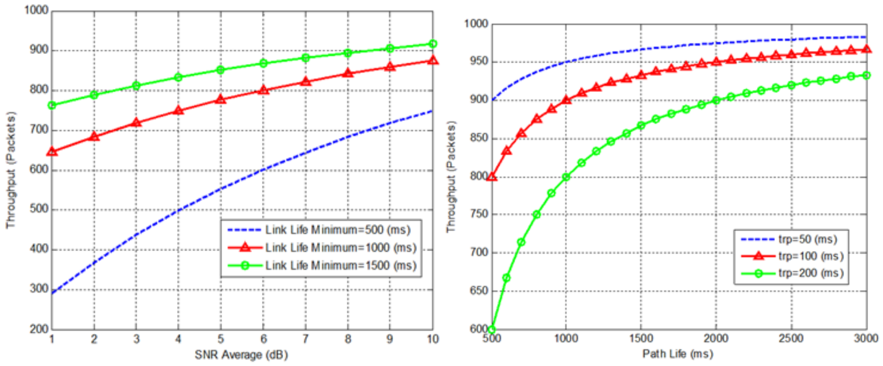

Figure 2: Throughput performance (a) with SNR average and the link life minimum (b) with path life and time to repair broken path.

in our study, the average path life ψ_{PL} will depend on the link life $T_{Link\ Life}$ and link quality Q_{link}. Hence, for node x and node y at time t_i to t_R, the link life is the length of the time interval between t_i and t_R. If $T_{Link\ Life}(t_i, t_R) = t_R - t_i$ and n is the number of nodes, then we can calculate the path life as the function link quality and link life as $\psi_{PL} = Q_{link} \min_{1 \le h \le n-1} T_{linkLife}(t_i(x_h, y_h), t_R(x_h, y_h))$. So, [4] can be express as

$$\boldsymbol{B} = \left(\mathbf{1} - \frac{\boldsymbol{t_{rp}}}{\boldsymbol{Q_{link}} \min_{1 \le h \le n-1} \boldsymbol{T_{linkLife}}(\boldsymbol{t_i}(\boldsymbol{x_h}, \boldsymbol{y_h}), \boldsymbol{t_R}(\boldsymbol{x_h}, \boldsymbol{y_h}))}\right) \boldsymbol{R}. \quad \textbf{[11]}$$

It can be seen from [11] that throughput has strong correlation with path life. While path life itself depends on link life and link quality. The throughput will increase when the link has both longer link life and higher SNR connection as shown in Figure 2.a. The network can gain higher throughput with longer path life as shown in Figure 2.b.

3. Result and discussion

Based on the analytical model above, that SNR has a strong correlation to path life and throughput performance, we proposed an enhancement on the routing protocol AODV that use minimum hop-count as the routing metric, and call it AODV SNR+. We employed a cross-layer approach between routing protocol in the network layer and the SNR ratio information from the physical layer. In this proposed scheme, the important aspect of this enhancement, which is not addressed in previous work, is that we utilize a combination of selective link based on SNR threshold (SNR_{thr}) in the reverse route process and the minimum SNR threshold (SNR_{minthr}) when the route error occurs. We apply SNR threshold as the criteria for a link to be used as path, which is called AODV SNR-SR (Istikmal, *et al.* 2017). Selective link will be made in the reverse path process. When in the network path break occurs due to decreasing amount of connection quality and there are no other available routes, RERR will be generated. In this situation, it is more difficult to find SNR connection that meets the SNR threshold criteria. Therefore, in this proposed method called SNR+, we used SNR_{thr} for normal situation, and switch to the minimum SNR threshold when RERR is generated. In this situation, the node that receives an RREQ with fresh and higher sequence number after route error (RERR) is generated will create the reverse route even when it does not meet the SNR_{thr} criteria. The SNR_{thr} will be replaced by SNR_{minthr}. Figure 3 shows the proposed AODV SNR+ route discovery process. The reason behind this algorithm is to accommodate situations where path breaks frequently occur and induce RERR.

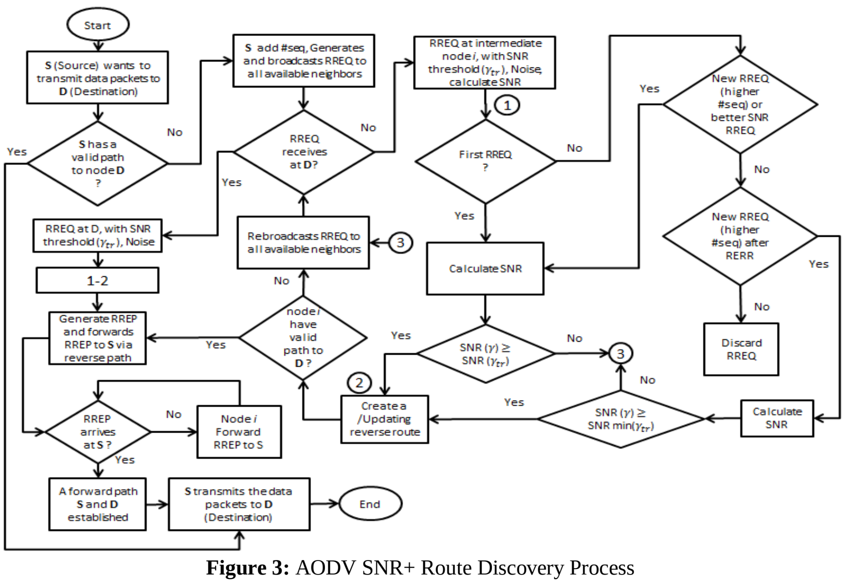

Figure 3: AODV SNR+ Route Discovery Process

We evaluate AODV SNR+ using Network Simulator 2.35 (source at http://www.isi.edu/nsnam/ns/ns-build.html) in various scenarios. Beside comparing with AODV, we also compared the AODV SNR+ with AODV SNR-SR. We assessed the throughput and routing overhead performance. The mobility model was random waypoint with simulation area of 1,000m x 1,000m. The data packet was 512 bytes, with channel bandwidth 2 Mb/s and simulation time 300 seconds. We used SNR Threshold 41 dB and minimum SNR threshold 33 dB. Maximum node speeds were set at 5 m/s, 10 m/s, 15 m/s, and 20 m/s and the number of traffic were 1, 2, 5, 7 and 9 sources. The simulation result in traffic scenarios showed that AODV SNR-SR outperformed AODV and AODV SNR+ as shown in Figure 4 (a). We observed that AODV SNR-SR yielded greater advantage of the throughput when the traffic was high. For example, in nine traffics, the advantage of AODV SNR-SR was about 20% and 61% higher as compared to AODV SNR+ and AODV schemes. In this situation, AODV SNR-SR has longest average path life as mentioned in [11]. The routing overhead of AODV SNR-SR outperforms AODV and AODV SNR+ as shown in Figure 4 (b). AODV SNR-SR has smallest routing overhead per received data packet. With 9-source traffics, the advantage AODV SNR-SR about 25.5% and 49.7% less overhead as compared to AODV SNR+ and AODV. To analyze routing overhead, we can calculate the route request in the reactive routing protocol by T/ψ_{PL}; so as the path life increases, the routing overhead decreases.

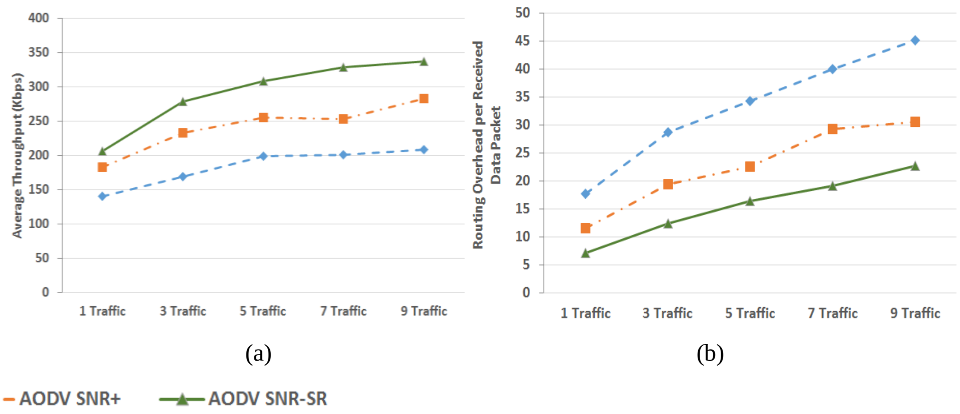

Figure 4: Average throughput (a) and routing overhead (b) comparison between AODV, AODV SNR-SR, and AODV SNR+ with increasing number of traffic source

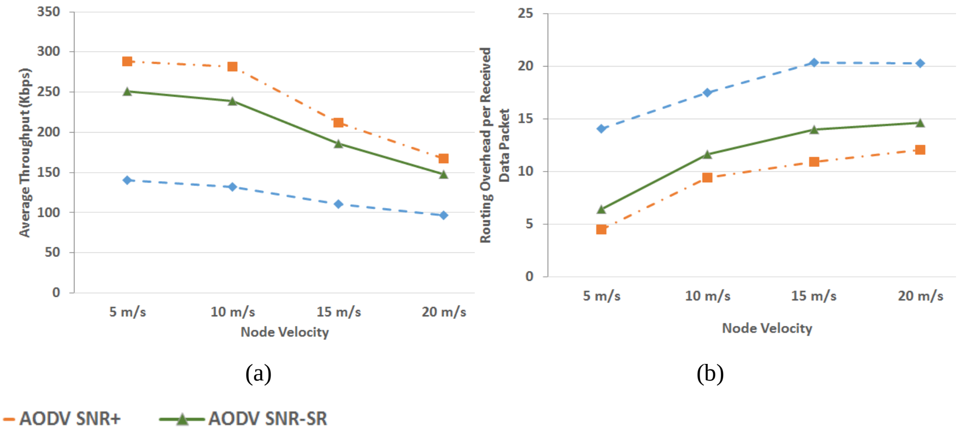

Figure 5: Average throughput (a) and routing overhead (b) comparison between AODV, AODV SNR-SR, and AODV SNR+ with increasing node velocity.

In mobility scenario, the result shows that the average throughput of AODV SNR+ outperforms AODV and AODV SNR-SR as shown in Figure 5 (a). When the node velocity increases, the throughput performance decreases. This mobility of node makes the path break frequently occurs, inducing RERR and new route discovery process. In this situation, the number of SNR connections that fail to meet the SNR_{thr} will increase, causing degradation of AODV SNR-SR performance. Meanwhile, AODV SNR+ can reduce the path break by using SNR_{minthr}, and get longer path life as expressed in [4, 11]. We observe that with this algorithm, AODV SNR+ can take advantages from the situation; for example, in node velocity 20 m/s AODV SNR+ outperforms about 12% and 42% higher throughput as compared to AODV SNR-SR and AODV respectively.

In this scenario, AODV SNR+ has longer path life with smaller routing overhead as shown in Figure 5 (b) by reducing RERR and repetition of transmission. For example, in 20m/s, AODV SNR+ yields less overhead as much as 17.6% and 40% as compared to AODV SNR-SR and AODV respectively. We analyze the correlation between routing overhead and RERR as follows. The routing overhead depends on the number of route requests by AODV. If a fraction γ of these requests need only one RREQ transmission to be replied by one-hop neighbors, then for the remaining fraction, which is $(1-\gamma)$, the routing overhead will depend on N transmission of the request. The route error (RERR) will induce the source to find a new route and increasing N transmission of the request, as well the overhead. Hence, we can express the overhead as $T/\psi_{PL}\left(1(\gamma)+(1-\gamma)N(1+nRERR)\right)$, with $nRERR$ is the number of RERR that induces source to find a new route.

4. Conclusion

In this paper, we construct throughput formula based on path life and link quality. We used path life based on SNR modeling for routing protocol improvement with a cross-layer scheme in wireless ad hoc networks. We develop routing protocol using a combination of selective link algorithm with an SNR threshold and the minimum SNR threshold for route error situation. We enhanced the reactive routing protocol AODV, which we call AODV SNR+. From the result, AODV SNR+ and AODV SNR-SR outperform AODV. We recommend AODV SNR-SR as more suitable for a stable mobility environment, and it can give a better advantage in higher traffic. On the other hand, AODV SNR+ can get more advantages in high mobility situations, where connection quality is decreasing.

Acknowledgments

This work is supported by the Ministry of Research Technology and Higher Education of the Republic of Indonesia, Telkom University, and YPT.

References

[1] B. Amiri, H. R. Sadjadpour and J. Garcia-Luna-Aceves, "Outage optimum routing for wireless networks," 7th International Wireless Communications and Mobile Computing Conference, Istanbul, pp. 1-6, 2011.
[2] B. Awerbuch, D. Holmer, and H. Rubens, "The Medium Time Metric: high throughput route selection in multi-rate ad hoc wireless networks," in journal of Mobile Networks and Applications, vol. 11, pp. 253–266, 2006.
[3] C. E. Perkins and E. M. Royer, "Ad-hoc on-demand distance vector routing," Mobile Computing Systems and Applications, 1999. Proceedings. WMCSA '99. Second IEEE Workshop on, New Orleans, LA, pp. 90-100, 1999.
[4] D. De Couto, D. Aguayo, J. Bicket, and R. Morris, "A high throughput path metric for multi-hop wireless routing", in proceedings of the 9th annual international conference on Mobile computing and networking, pp. 134-146, San Diego, September, 2003.
[5] F. Bai, N. Sadagopan, B. Krishnamachari and A. Helmy, "Modeling path duration distributions in MANETs and their impact on reactive routing protocols," in IEEE Journal on Selected Areas in Communications, vol. 22, no. 7, pp. 1357-1373, Sept. 2004.
[6] Fuad Alnajjar, "SNR/RP Aware Routing Model for MANETs," in Cyber Journals: Multidisciplinary Journals in Science and Technology, Journal of Selected Areas in Telecommunications (JSAT), March Edition, pp. 40-48, 2011.
[7] Istikmal, Adit Kurniawan, and Hendrawan. Selective Route Based on SNR with Cross-Layer Scheme in Wireless Ad Hoc Network. Journal of Computer Networks and Communications, volume 2017 (2017), article ID 1378374.
[8] K. Kunavut, "Link quality aware routing based on effective estimated throughput for mobile ad hoc networks," International Symposium on Intelligent Signal Processing and Communication Systems, Naha, pp. 487-492, 2013.
[9] M. Elshaikh, M. F. M. Fadzil, N. Kamel and C. M. N. C. Isa, "Weighted Signal-to-noise ratio average routing metric for Dynamic Sequence Distance Vector routing protocol in mobile ad-hoc networks," IEEE 8th International Colloquium on Signal Processing and its Applications, Melaka, pp. 329-334, 2012.
[10] Network Simulator, NS 2.35. http://www.isi.edu/nsnam/ns/ns-build.html.
[11] R. Aguero, J. A. Galache and L. Munoz, "Using SNR to Improve Multi-Hop Routing," VTC Spring - IEEE 69th Vehicular Technology Conference, Barcelona, pp. 1-5, 2009.
[12] R. Edirisinghe and A. Zaslavsky, "Cross-Layer Contextual Interactions in Wireless Networks," in IEEE Communications Surveys & Tutorials, vol. 16, no. 2, pp. 1114-1134, Second Quarter 2014.
[13] R. Draves, J. Padhye and B. Zill, "Routing in multi-radio, multi-hop wireless mesh networks," in proceedings of the 10th annual international conference on Mobile computing and networking, pp. 114–128, Sep. 2004.
[14] Shengming Jiang, Member, IEEE, Dajiang He, and Jianqiang Rao. A Prediction-Based Link Availability Estimation for Routing Metrics in MANETs. IEEE/ACM transactions on networking, vol. 13, no. 6, Desember, 2005.
[15] S. Mumtaz, K. M. Saidul Huq and J. Rodriguez, "Direct mobile-to-mobile communication: Paradigm for 5G," in IEEE Wireless Communications, vol. 21, no. 5, pp. 14-23, October, 2014.
[16] Xiaoheng Deng, Qiang Liu, Xu Li, Lin Cai and Zhigang Chen,"Channel quality and load aware routing in wireless mesh network," 2013 IEEE Wireless Communications and Networking Conference (WCNC), Shanghai, 2013, pp. 2068-2073.