https://doi.org/10.46335/IJIES.2024.9.4.5 e-ISSN: 2456-3463
Vol. 9 , No. 4, 2024, PP. 25-29

International Journal of Innovations in Engineering and Science, www.ijies.net

Mobility Models in Opportunistic Network: A Review

Ashish T. Bhole[1], Dr. Girish Kumar Patnaik[2]

[1]Associate Professor, SSBT's College of Engineering & Technology, KBC North Maharashtra University, Jalgaon, India, Pincode: 425001
[2]Principal, SSBT's College of Engineering & Technology, KBC North Maharashtra University, Jalgaon, India, Pincode: 425001

Email ID: ***ashishbhole11@gmail.com, patnaik.girish@gmail.com***

Received on: 19 April, 2024 **Revised on**: 21 May, 2024 **Published on**: 22 May, 2024

Abstract- *Recent developments in wireless networks have resulted in new paradigms. The Opportunistic Network (OppNet) is a type of Delay Tolerant Network (DTN). Performance of Opportunistic Network greatly depends on routing protocols and mobility models. The paper presents classification and review of mobility models available for use in Opportunistic Network. Random mobility model, Map-based mobility model, Social relationship-based mobility model and Hybrid mobility models are studied and reviewed.*

Keywords- *Wireless network, Mobile ad hoc network (MANET), delay tolerant network (DTN), opportunistic network (OppNet), performance, mobility model*

I- INTRODUCTION

An Opportunistic Network falls under the category of Delay-Tolerant Networks, characterized by sporadic communication opportunities among devices. Consequently, maintaining a continuous connection between the source and destination is not always feasible. Opportunistic networks find application in environments where a high error rate and extended delays are deemed acceptable [1].

Despite the rapid advancement of communication technologies in the 21st century, offering swifter, more dependable, and secure connectivity, traditional wireless networks such as Mobile Ad-hoc Networks (MANET), Wireless Sensor Networks, and Wireless Mesh Networks face operational challenges that can compromise network performance. In response to these difficulties, researchers have introduced innovative network topologies, giving rise to the emergence of Opportunistic Networks [2].

Opportunistic Networks represent a subtype of delay-tolerant networks formed by nodes capable of supporting such networks. However, they grapple with several challenges, including high node mobility, low power, restricted radio communication range, sparse node density, and susceptibility to network attacks initiated by malicious nodes [3].

II-OPPORTUNISTIC NETWORK (OppNet)

An Opportunistic Network (OppNet) typically involves a variety of mobile wireless devices, like portable devices carried by mobile users and vehicles, forming dynamic clusters or connectivity islands. These devices leverage radio contacts with peers whenever possible and collaborate to route data. The transfer of data from source to destination in OppNets may require multiple intermittent wireless contacts or hops over time [4].

In Opportunistic networks, the mobility of nodes is viewed as an opportunity rather than a hindrance [5].

https://doi.org/10.46335/IJIES.2024.9.4.5 **e-ISSN: 2456-3463**
Vol. 9 , No. 4, 2024, PP. 25-29

Node movement creates chances for establishing contact between nodes, facilitating connections in different parts of the network that might otherwise be disconnected.

OppNets prioritize content-centric data dissemination over user-centric dissemination. The spread of data relies on individuals' mobility patterns and their shared content interests. Due to these characteristics, OppNets are considered a potential supplement to existing infrastructure [6].

To develop effective solutions for the future internet, it's essential to understand the characteristics of human social relationships in the integrated cyber-physical world [7]. Often, devices in the cyber world act as proxies for their users in the physical world, mirroring their daily routines and behaviors, such as smartphones constantly carried by users. As a result, the structures and features of human social relationships can seamlessly translate into relationships between users' devices, forming the basis for networking solutions. Opportunistic networking marks an evolution from the traditional MANET paradigm, where having simultaneous end-to-end paths between two endpoints is not mandatory for communication.

III- MOBILITY MODELS IN OPPORTUNISTIC NETWORK

Mobility models aim to depict user movement patterns using changes in both location and velocity over time. Understanding these human movement patterns is vital for evaluating the performance of a protocol, given that mobility creates opportunities for contacts and subsequent communication.

The efficacy of OppNets is indirectly determined by the choice of mobility model for network deployment. Mobility within networks generates chances for contact and inter-contact communication. Camp T et al. [8] have proposed numerous mobility models.

A) Random Mobility Model

Models incorporating random movements utilize stochastic patterns to direct a node within a designated area. Among various simulation scenarios, people often use the Random Way Point (RWP) model because it's easy to use. In this model, a mobile device picks a random place to go and moves there at a randomly chosen speed.

The random model epitomizes uncomplicated mobility models, allowing mobile nodes to traverse in any arbitrary direction [9][10][11].

In the random walk (Brownian motion) model [12], A node decides which way to go and how fast, then keeps moving that way for a set amount of time. Afterwards, it independently chooses a new direction and speed. This random walk can occur in either one or two dimensions.

The random waypoint model [13] closely mirrors the random walk model, with the distinction that after completing movement in one direction, a node pauses for a predetermined duration before resuming.

With random direction model, a node keeps moving until it reaches the edge of the simulation area in the chosen direction. Once it hits the edge, the node can pick a new direction and speed. This model increases the chance of having an even spread of nodes in simulations [14][15].

The Levy Walk model closely resembles the Random Walk, but with movement lengths and pause times derived from a power law distribution [14][16]. This model has the ability to replicate an inter-contact time distribution closely resembling many real-world traces.

Several mathematical models have been suggested to simulate the random movement of nodes, including probabilistic random walk, boundless simulation, and the Gauss Markov model [9][10][11]. These models use mathematical formulas to decide on the next direction, speed, and time interval when moving from one point to another.

However, the use of random models comes with a significant drawback as they lack realism compared to real-life scenarios. In actuality, human movement is not entirely random; individuals typically move towards specific destinations such as offices, homes, or shopping complexes. Furthermore, random models neglect obstacles present in real-world settings, such as buildings and forests, where actual movement often follows specific streets and walkways.

B) Map-based Mobility Model

The enhanced mobility model, an extension of the Random Waypoint (RWP), can be further classified as a mobility model with geographic constraints or a map-based mobility model, where movement is limited by streets or obstacles. Map-based models strive to present the authentic representation of node mobility.

With random map-based model, nodes have to choose a destination from a list given beforehand, and their speed is randomly set. They're constrained to follow street routes as per the map and can't go through buildings or walls or change direction in the middle of a street.

With shortest path map-based model [17], the destination is picked from valid points on the map, and the path to reach that destination is found using shortest path algorithms such as Dijkstra's algorithm.

With route-based model, nodes have to stick to pre-defined routes or paths., much like the patterns observed in trains, buses and similar transportation systems [18].

The Manhattan Mobility Model serves as another widely used Map Constrained Mobility Model. This method is used to mimic movement in urban settings where mobile devices rely on computing services. The map is divided into horizontal and vertical grids, and probabilities within these grids help decide the next destination.

The Rush Hour Mobility Model [19] notes the rise in node traffic during rush periods, identifying the source and destination of the traffic. It characterizes conditions before and after the surge in node traffic, specifying each location with its geographic coordinates, node origin, node interval, and minimum and maximum location ranges. This model provides a more accurate representation of real-world traffic nodes.

In the Obstacle Mobility Model [20], nodes exhibit random movement, bouncing off structures such as buildings and electric poles. Key features of obstacle-based mobility models involve defining object spaces and sizes, as well as providing a mapped route to indicate object locations, allowing nodes to adjust their directions as needed. At the start of the simulation, the positions of objects and connecting routes are established and stay the same throughout.

In the Pathway Mobility Model, the simulation field illustrates the vertices of graphs representing buildings, connected by street edges to facilitate nodes in finding pathways between them. Initially positioned randomly, nodes are permitted to select random destinations and move based on the supplied map.

A limitation of map-based models is their greater suitability for vehicular networks, often overlooking social context information in movement decisions.

C) Social-based Mobility Model

In an alternative extended mobility model with spatial dependency or a social-based mobility model, it introduces changes in movement in a correlated manner.

Social-based mobility models are based on human behavior, such as where people live and work [21], which affects how nodes move. For example, in the morning, there's a higher chance of people heading to their workplaces.

The Clustered Mobility Model (CMM) [22] incorporates social data by giving nodes values ranging from 0 to 1, reflecting their social interactions with another mobile nodes in the network.

The Home Cell Mobility Model (HCMM) [23] tracks the locations that are visited most often, like home or office addresses, showing preferences for specific physical locations.

The Working Day Model (WDM) [24] further considers the time and day to determine node mobility concerning physical location such as on weekdays, nodes are more likely to travel towards their office locations compared to weekends.

Social networks have been extensively explored across various disciplines, and the Social Network Model [25] is designed to emulate properties found in networks consist of scale-free or small-world models, with a notable emphasis on clustering. Given that humans commonly organize themselves in communication structures, social networks are closely linked to human behavior.

With Time-Variant model, whole simulation area is broke down into smaller parts as communities, with each node belonging to one community. Nodes are endowed with a fixed global velocity, enabling movement between communities. The arrangement of communities and their transition probabilities remains constant for a specific time period.

The General Social Model (GeSoMo) [26] takes social networks as input and generates traces that serve as time table for node movement. It generates records of interactions between nodes to demonstrate social connections, aiming to describe a real-world human social mobility model.

However, these models may not be highly beneficial for evaluating Opportunistic Networks (OppNets) because the mobility patterns in OppNets should mimic human behavior. Human movement is influenced by daily activities (at home, school, or work), means of transportation (walking, biking, bus, etc.), and the behavior of other users in their local environment. Many of these activities are intricately connected to user behavior and social relationships [27][28].

D) Real Mobility Traces

A wide range of datasets has been collected by observing the mobility of nodes in real-world situations. These traces offer precise information, especially when obtained from a large number of participants over an extended period. Traces can be broadly categorized as contact-based and location-based.

Contact-based traces involve measuring the times contacts occur between pairs of nodes within a specified time interval. Prominent datasets such as Infocom [29], Cambridge [30], Milano [31], and MIT (or Reality) [32] have been extensively utilized, and their statistical properties have been thoroughly examined [33][34].

While these traces offer simplicity for analytical evaluation and straightforward simulation of Opportunistic Networks (OppNets), their notable drawback lies in their inability to simulate the impact of communication protocols. Therefore, to assess these aspects, location-based traces are indispensable. These traces involve obtaining the nodes' locations, typically their GPS coordinates are logged periodically or whenever nodes move. Different types of traces are available, such as taxi movement in Shanghai [35] or student movement on the National Chengchi University campus [36]. The Crawdad repository [37] stands as a comprehensive source for publicly available traces and is a primary reference for simulations.

E) Hybrid Mobility Models

The hybrid category combines elements from various Random Mobility Models and Real Mobility traces. In these models, parameters such as the frequency of user movements based on locations in a random model are determined from either a collection of traces or user experiences.

Hybrid models aim to replicate real human movements by incorporating not only common-sense assumptions but also analysis from traces. In terms of performance and scalability, hybrid models outperform real mobility traces. Numerous studies focus on developing realistic mobility models grounded in social relationships, including hybrid models considering users' frequent travels over short distances, movements influenced by social connections between users, and their location preferences. Examples of these models include SWIM [38], HCMM [23], and the Working Day Model (WDM) [24].

IV- CONCLUSION

The mobility model dictates the algorithm and regulations governing the generation of paths for node movement within a network. In Opportunistic Networks, mobility models deviate from those utilized in conventional networks. Hybrid models combine the random mobility model with real mobility traces, aiming to replicate genuine human movements by considering The hybrid models leverage not just natural beliefs but also data analytics from traces. They demonstrate improved performance and scalability compared to real mobility traces.

REFERENCES

[1] *Huang, Chung-Ming, Kun-chan Lan, and Chang-Zhou Tsai. "A survey of opportunistic networks." In 22nd International conference on advanced information networking and applications-workshops (aina workshops 2008), pp. 1672-1677. IEEE, 2008.*

[2] *Mohandas, Geethu, Salaja Silas, and Shini Sam. "Survey on routing protocols on mobile adhoc networks." In 2013 International Mutli-Conference on Automation, Computing, Communication, Control and Compressed Sensing (iMac4s), pp. 514-517. IEEE, 2013.*

[3] *Khabbaz, Maurice J., Chadi M. Assi, and Wissam F. Fawaz. "Disruption-tolerant networking: A comprehensive survey on recent developments and persisting challenges." IEEE Communications Surveys & Tutorials 14, no. 2 (2011): 607-640.*

[4] *Mitra, Pramita, and Christian Poellabauer. "Opportunistic Routing in Mobile Ad Hoc Networks." In Routing in Opportunistic Networks, pp. 145-178. Springer New York, 2013.*

[5] *Conti, Marco, and Stefano Giordano. "Mobile ad hoc networking: milestones, challenges, and new research directions." Communications Magazine, IEEE 52, no. 1 (2014): 85-96.*

[6] *Trifunovic, Sacha, Sylvia T. Kouyoumdjieva, Bernhard Distl, Ljubica Pajevic, Gunnar Karlsson, and Bernhard Plattner. "A decade of research in opportunistic networks: challenges, relevance, and future directions." IEEE Communications Magazine 55, no. 1 (2017): 168-173.*

[7] *Passarella, Andrea, Robin IM Dunbar, Marco Conti, and Fabio Pezzoni. "Ego network models for future internet social networking environments." Computer Communications 35, no. 18 (2012): 2201-2217.*

[8] *Camp T, Boleng J, Davies V. A survey of mobility models for ad hoc network research. Wireless Commun Mob Comput. 2002;2(5):483-502. https://doi.org/10.1002/wcm.72*

[9] *Lin G, Noubir G, Rajaraman R. Mobility models for ad hoc network simulation. IEEE INFOCOM. 2004:454-463. https://doi.org/10.1109/infcom.2004.1354517*

[10] *Harri J, Filali F, Bonnet C. Mobility models for vehicular ad hoc networks: a survey and taxonomy. IEEE Commun Surv Tut. 2009;11 (4):19-41. https://doi.org/10.1109/surv.2009.090403*

https://doi.org/10.46335/IJIES.2024.9.4.5 **e-ISSN: 2456-3463**
Vol. 9 , No. 4, 2024, PP. 25-29

International Journal of Innovations in Engineering and Science, www.ijies.net

[11] *Mota VFS, Cunha FD, Macedo DF, Nogueira JMS, Loureiro AAF. Protocols, mobility models and tools in opportunistic networks: a survey. Comput Commun. 2014;48:5-19. https://doi.org/10.1016/j.comcom.2014.03.019*

[12] *A. Sharma, G., and J. Singh, "Mobility Models for MANET: Mathematical Perspective," vol. 2, May 2013.*

[13] *S. Kaur, H. Singh, T. Singh, and Y. Singh, "Mobility Models in Ad hoc Networks," vol. 3, Nov. 2012*

[14] *M. Shahzamal, M. F. Parvez, M. A. U. Zaman, and M. D. Hossain, "Mobility Models for Delay Tolerant Network: A Survey," International Journal of Wireless & Mobile Networks, vol. 6, no. 4, pp. 121–134, 2014.*

[15] *A. Riberio and R. C. Sofia, "A survey on mobility models for wireless Networks", 2011*

[16] *B. Rani and Shailaja, "A Review of Mobility Models in Delay Tolerant Network," International Journal for Innovative Research in Science & Technology, vol. 2, no. 3, pp. 18–21, Aug. 2015.*

[17] *Soares VNGJ, Rodrigues JJPC, Farahmand F. Impact analysis of the shortest path movement model on routing strategies for VDTNs in a rural region. In: Proceedings of 7th Conference on Telecommunications, CONFTELE 2009.*

[18] *Keränen, Ari, and Jörg Ott. "Increasing reality for dtn protocol simulations." Helsinki University of Technology, Tech. Rep 2007.*

[19] *W. K. Seah, F. W. Lee, K. W. Mock, E. K. Ng, and M. Kwek, "Mobility Modeling of Rush Hour Traffic for Multihop Routing in Mobile Wireless Networks," IEEE Vehicular Technology Conference, 2006.*

[20] *A. Jardosh, E. M. Belding-Royer, K. C. Almeroth, and S. Suri, "Towards realistic mobility models for mobile ad hoc networks," Proceedings of the 9th annual international conference on Mobile computing and networking - MobiCom '03, 2003.*

[21] *Karamshuk D, Boldrini C, Conti M, Passarella A. Human mobility models for opportunistic networks. IEEE Commun Mag. 2011;49 (12):157-165. https://doi.org/10.1109/mcom.2011.6094021*

[22] *Musolesi M, Mascolo C. Designing mobility models based on social network theory. ACM SIGMOBILE Mob Comput Commun Rev. 2007;11(3):59-70. https://doi.org/10.1145/1317425.1317433*

[23] *Boldrini C, Passarella A. HCMM: modelling spatial and temporal properties of human mobility driven by users' social relationships. Comput Commun. 2010;33(9):1056-1074. https://doi.org/10.1016/j.comcom.2010.01.013*

[24] *Ekman F, Keränen A, Karvo J, Ott J. Working day movement model. Proceeding of the 1st ACM SIGMOBILE Workshop on Mobility Models—MobilityModels'08. 2008. https://doi.org/10.1145/1374688.1374695*

[25] *M. Musolesi, S. Hailes, and C. Mascolo, "An ad hoc mobility model founded on social network theory," Proceedings of the 7th ACM international symposium on Modeling, analysis and simulation of wireless and mobile systems - MSWiM '04, 2004.*

[26] *M. Shahzamal, M. F. Parvez, M. A. U. Zaman, and M. D. Hossain, "Mobility Models for Delay Tolerant Network: A Survey," International Journal of Wireless & Mobile Networks, vol. 6, no. 4, pp. 121–134, 2014.*

[27] *F. Bai and A. Helmy, "A survey of mobility models," 2004.*

[28] *T. Camp, J. Boleng, and V. Davies, "A survey of mobility models for ad hoc network research," vol. 2, no. 5. Wiley Online Library, 2002, pp. 483–502.*

[29] *P. Hui, A. Chaintreau, J. Scott, R. Gass, J. Crowcroft, and C. Diot, "Pocket switched networks and human mobility in conference environments," in Proceedings of the 2005 ACM SIGCOMM Workshop on Delay-Tolerant Networking, ser. WDTN '05. New York, NY, USA: ACM, Aug. 2005, pp. 244–251.*

[30] *J. Leguay, A. Lindgren, J. Scott, T. Friedman, and J. Crowcroft, "Opportunistic content distribution in an urban setting," in Proceedings of the 2006 SIGCOMM Workshop on Challenged Networks, ser. CHANTS'06. New York, NY, USA: ACM, Sept. 2006, pp. 205–212.*

[31] *S. Gaito, E. Pagani, and G. Rossi, "Fine-grained tracking of human mobility in dense scenarios," in Proceedings of the 6th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks Workshops, 2009. SECON Workshops '09., Rome, Italy, June 2009, pp. 1–3.*

[32] *N. Eagle and A. Pentland, "Social serendipity: mobilizing social software," Pervasive Computing, IEEE, vol. 4, no. 2, pp. 28–34, Mar. 2005.*

[33] *A. Passarella and M. Conti, "Characterising aggregate inter-contact times in heterogeneous opportunistic networks," in Proceedings of the 10th International IFIP TC 6 Conference on Networking - Volume Part II, ser. NETWORKING'11. Berlin, Heidelberg: Springer-Verlag, May 2011, pp. 301–313.*

[34] *E. Hernández-Orallo, J. C. Cano, C. T. Calafate, and P. Manzoni, "New approaches for characterizing inter-contact times in opportunistic networks," Ad Hoc Networks, Special Issue on Modeling and Performance Evaluation of Wireless Ad Hoc Networks, vol. 52, pp. 160 – 172, Dec. 2016.*

[35] *H. Zhu, L. Fu, G. Xue, Y. Zhu, M. Li, and L. M. Ni, "Recognizing exponential inter-contact time in VANETs," in Proceedings of the 29th Conference on Information Communications, ser. INFOCOM'10. Piscataway, NJ, USA: IEEE Press, Mar. 2010, pp. 101–105.*

[36] *T.-C. Tsai and H.-H. Chan, "NCCU Trace: social-network-aware mobility trace," IEEE Communications Magazine, vol. 53, pp. 144–149, Oct. 2015.*

[37] *University of Dartmouth, "CRAWDAD: A community resource for rchiving wireless data." [Online]. Available: http://www.crawdad.org*

[38] *A. Mei and J. Stefa, "SWIM: A simple model to generate small mobile worlds," CoRR, vol. abs/0809.2730, Apr. 2008.*