Journal of Information Systems Engineering and Management
2025, 10(43s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Study of Light Weighted Protocols in Integrated MANET-WSN Setting in Urban Environment

Ms. Gaurvi Shukla[1], Dr. Satyabhushan Verma[2], Ms. Shweta Sinha[3]
[1]*Research Scholar, Shri Ramswaroop Memorial University*
[2]*Associate Professor, Shri Ramswaroop Memorial University*
[3]*Research Scholar, Shri Ramswaroop Memorial University*

ARTICLE INFO

Received: 18 Dec 2024

Revised: 10 Feb 2025

Accepted: 28 Feb 2025

ABSTRACT

For the development of urban area with scalable, reliable and efficient infrastructure, the setting and study of light weighted protocols in Integrated MANET-WSN architecture is crucial. The challenges like energy efficiency of node, maintaining dynamic topology, packet latency, MANET node density and the need of uninterrupted secured real time communication. In this situation, lightweight communication protocols are needed to minimize latency, reduce overhead and in this way extend the battery life of sensor nodes. Protocols like ZigBee, RPL, DASH7 and Bluetooth LE must be optimized while maintaining throughput, data integrity and low rate packet loss. The integrated MANET and WSN technologies provide a hybrid architecture where the mobile sensor nodes can dynamically enhance the network coverage and support sensor node flexibility. The above mentioned protocols are used for light weighted routing and we already compared these protocols further in this research paper along with IPv6 support, network specification, standard body, standard documentations, data rate, nominal range and physical specifications. Moreover, the protocols adapt frequent changes in topology and thus reliable for the applications like traffic management, public safety and monitoring environmental changes. This paper highlights the comparison of existing light weighted protocols and recommends the integrated MANET-WSN model, targeting specifically adaptability, energy efficiency, protocol overhead and quality service. This paper aims to enhance the protocol performance in hybrid manner and improve the overall quality life style for city residents.

Keywords: MANET, WSN, Latency, light weighted protocol, Cluster

Introduction: Various research studies, In the previous decade analyzed emerging Internet of Things (IoT) application models that unify diverse devices from wireless sensors to smart phones and network-based physical objects such as RFID and smart visual tags [1]–[3]. Research activities in IoT technologies and related standards continue to grow due to the rise of smart cities that aim to create "intelligent wide-scale open environments" for assisting citizens in their daily life quality improvements. The collection of data from smart objects through participatory sensing will lead standardization initiatives under various perspectives to handle unpredictable deployment scenarios with open systems conditions. Creating new adaptable autonomic services presents itself as a significant objective for smart city. A multidepartment smart city system includes applications ranging across environmental monitoring and habitability analysis (noise/light pollution detection among others) of environmental and habitability monitoring.

The system requires monitoring of various aspects including security and environment (pollution and vehicle traffic) and residential status control along with structural safety protocols and antitheft solutions. These services aim to assist citizenship urban living and roaming by helping elderly citizens with their assistance needs along with functioning as emergency response systems etc. [4]. New wireless solutions and mobile devices enable original connection possibilities for delivering fresh service options. The term Wireless Sensor Networks (WSNs) describes a network consisting of inexpensive tiny autonomous devices which function using sensors to collect information. WSN

Journal of Information Systems Engineering and Management
2025, 10(43s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

systems consist of devices that combine sensors with the capability to measure data while storing the data locally and managing sensor signals and allowing inter-network communication. The advancement of wireless ad-hoc technologies through last decade has led to the creation of Mobile Ad-hoc NETworks (MANETs) which allow for instant network formation without rigid infrastructure requirements. The distinction between WSNs which consist of things and MANETs which consist of people, exists due to their dynamic network creation that enables restricted-area users to transfer data without requiring an infrastructure base or central management. The combination of Wireless Sensor Networks (WSNs) and Mobile Ad-hoc NETworks (MANETs) stands as key technologies which enable various IoT application domains in smart cities according to [5]. The deployment of these networks becomes simpler because their localities with their automatic configuration abilities help large-scale projects. Market research indicates that municipalities will implement WSNs and MANETs because public safety and environmental monitoring and location services will be among the primary utilization areas [6] and the Republic of Korea serves as an exemplary case by recently allocating funds for WSN-related technology implementations to serve diverse citizen-specific applications [7].

2. Guidelines and Requirements for Standardization:

WSN and WSN-MANET integration needs middleware solutions to develop into a practical technology which supports the cost-effective implementation of the IoT vision. We believe middleware solutions at the standards-compliant layer (or specifications-based layer) are needed to achieve cost-effectiveness and deploy ability of the IoT vision.

The central hardware standard requires smart phones to have low-power wireless interfaces that establish WSN connectivity for interworking with MANETs at reduced expense. The main focus of software-related standards is packet routing and high-level network management which aims to produce interoperability and integration capabilities between WSNs and mobile devices. Multiple competing proposals exist in this particular field at present. Bluetooth Low Energy (Bluetooth LE) stands out as one of the main standards alongside Developers Alliance for Standards Harmonization of ISO 18000-7 (DASH7) and IPv6 Routing Protocol for Low-power and lossy networks (RPL and ZigBee [9]–[12]. Table 1 shows their major characteristics because each protocol addresses distinct market sectors leading to varying balances between data rate and coverage range and routing capabilities. The physical-layer characteristics of Bluetooth LE enable Body/Personal Area Network functionality through its specific design for short-range operations. The technology selects short-distance communication with fast data transfer. The reduced power consumption of Bluetooth LE functions better than conventional Bluetooth because of its design characteristics. Duty cycling support enhancement in small data bursts is the result of improved operations but continuous data transmission leads to equivalent power consumption rates as standard Bluetooth. The power usage of Bluetooth LE matches Bluetooth standards when streams are active.

Table1: Comparison of some low power protocols and their standards

Name	*Standard body*	*Standard document*	*Physical specification*	*Nominal Range (0dBm)*	*Data rate*	*Network specification*	*IPv6 support*
Bluetooth LE	Bluetooth SIG	Bluetooth Core 4.0	Yes (short range, high data rate)	10 m	1 Mbps	Star topology	Yes (IETF draft)
DASH7	DASH7 Group, ISO	ISO/IEC 18000-7:2009	Yes (long range, low data rate)	250 m	28-200 Kbps	No	No
RPL	IETF	IETF ROLL WG	No	N/A	N/A	Mesh	Yes
ZigBee	ZigBee Alliance, IEEE	IEEE 802.15.4-2006	Yes (medium range, medium data rate)	75 m	250 Kbps	Mesh	Yes (draft)

The most promising proposals for WSNs are ZigBee because their standards have stabilized and many industries provide broad support. The adoption of WSNs for IoT applications in smart cities will receive tremendous support from these proposals.

3. Reference Model: WSNs deployed at scales throughout smart cities achieve multiple interesting capabilities because they can combine with mobile devices. The main purpose of our work focuses on establishing affordable solutions for large-scale urban monitoring implementations. The typical structural monitoring applications use this reference scenario with specified requirements and features. Any monitoring application that requires different urgency levels for alarm situations presents features that our proposal suits those environments. The key requirement for communication solutions between MANETs and WSNs is to create protocols that minimize node-to-node contact when transferring urgent data. This research builds upon our previous work which explored "A Decentralized Distribution of WSN." [13].

The current article concentrates on MANET aspects regarding the integration. The following sections of this paper demonstrate the core coordination and clustering functions which operate at MANET nodes when integrating WSN-MANET into IoT environments. MANET deployments encounter several problems with mobility and scalability which require new solutions and standards for small local cluster organization. The existence of large and dense MANET deployments requires new organizational solutions and standards which we present in detail hereafter. A new organizational framework must exist together with standards which guide the arrangement of MANET nodes in small clusters. The proposed solution is mentioned in detail in the following discussion about local clusters. Roots are sensor nodes that the system allows collection tree roots to announce their availability for connection as gateways to the Internet. All other sensor nodes collected data from sensor nodes utilizes routing trees to transmit information toward roots located at the WSN layer. A WSN exit point refers to any WSN node which has at least one visible MANET node.

A node from the MANET network must have visibility to at least one MANET node to jump urgent data. The MANET receives data from a WSN entry point which represents the WSN node with the lowest gradient cost that the MANET cluster can reach. Entry and exit points in MANET belong to the MANET network. A two-way data flow is enabled between the WSN entry points as they both receive incoming data from WSN and forward that data through the MANET-WSN. The proposed solution spans across all major tree-based sensor data collection standards and research-oriented protocols including IETF, RPL and CTP. The field recognizes IETF and RPL as a very promising standard specification. The existing number of examples remains quite limited at this time. The deployment of this solution faces challenges Therefore, in our current prototype to make our proposal fully compatible during its current development stage, CTP enables robust operation because its extensive performance evaluation and active developer community. The proposal uses CTP because its developer community remains active. The gradient value of each sensor node equals to the sum of expected transmission hops required to reach the root. The gradient value of a sensor node equals the total number of transmission hops needed to send a packet to the root node [15].

The cluster head generates periodic hop-limited keep-alive packets that travel through intermediate nodes to reach different intermediate nodes and leaves to maintain cluster extension. The cluster lifetime receives its fixed duration through consideration of both MANET node numbers and discovery functions frequency [13]. Cluster lifetime naturally ends when keep-alive packets stop being renewed and this event causes the cluster to disappear while nodes revert to an idle state. Each MANET node belongs to multiple clusters although it functions only as a cluster head in one cluster only.

4. **Results**: The cluster formation protocol begins its operation through any MANET node serving as a cluster head which detects urgent data packets being routed on the WSN. Any MANET node acting as a cluster head can start the cluster formation protocol through monitoring urgent data packets. Any node functioning as cluster head initiates the cluster formation protocol when it detects an urgent data packet being routed through the WSN. The MANET system uses the same communication method which appears in Fig. 1. Each MANET node communicates to the cluster head for joining the new cluster. The cluster nodes provide responses to the MANET while the cluster head selects the exit point through the network. The selected exit node for data transmission will be the one which provides

Journal of Information Systems Engineering and Management
2025, 10(43s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

the best gradient. The cluster head obtains message estimates from every participating node of the cluster through this process. The duration of policy-based message transmission between WSN and MANET can be determined through suitable configuration parameters. The integration period should be determined with energy requirements as the main consideration [13]. The said property creates an exceptional framework for protecting urgent data throughout network operations. The cluster head succeeds in urgent packet routing because it chooses the destination node with superior gradient properties.

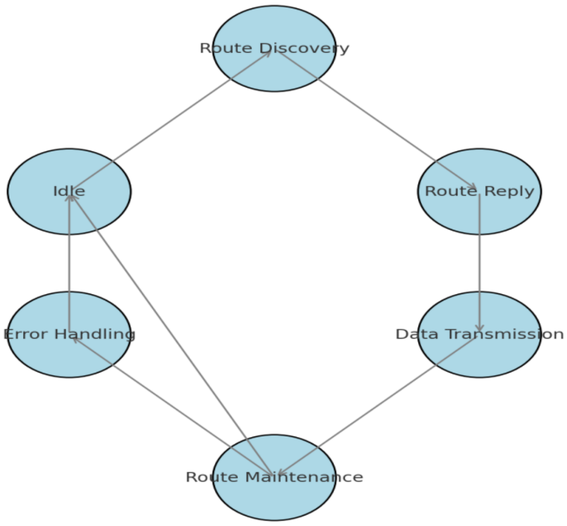

Fig 1: State diagram of MANET coordination protocol

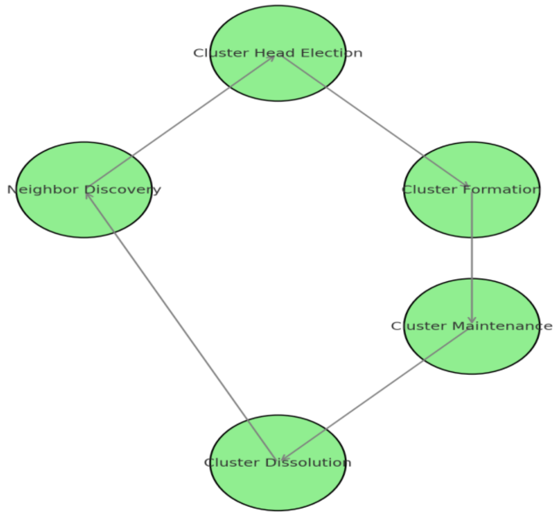

Fig 2: Phases of MANET Cluster Formation

An idle node receives urgent packets from the cluster head by using the designated routing path. The urgent packet remains on track for forwarding at every network hop to a MANET node with a better gradient than previous hop. The participation of all members of the MANET network in the path enables the process. The WSN nodes located inside the cluster maintain constant visibility of each other despite possible path disruptions. The disruption of the final MANET exit point occurs because of node mobility. The data packet maintains its ability to be routed backward by intermediate nodes. The WSN will obtain at least a suboptimal performance level regardless of the data routing outcome.

The model represents MANET node functions through a finite state machine system. A finite state machine represents the various roles which MANET nodes adopt in a cluster model as shown in Fig. 2. The MANET network begins its operation from the IDLE state. The nodes in this state conduct error handling and route maintenance of WSN but remain inactive for other activities. Urgent packets will be directed through the underlying WSN by MANET nodes. The MANET node enters a new state when it intercepts an urgent packet through snooping.

A new state activates in which the node distributes a join request through broadcast to surrounding MANET nodes. The request travels to neighboring MANET nodes to seek cluster membership in the new group. A cluster head role belongs to the sender node at this moment. Then, the potential cluster head remains in this state to receive replies from MANET nodes located in the surrounding area. A MANET cluster formation will succeed when any single MANET node accepts cluster membership. The node transforms into a cluster head when joining a cluster. However when no nodes join the process, it returns back to the idle state.

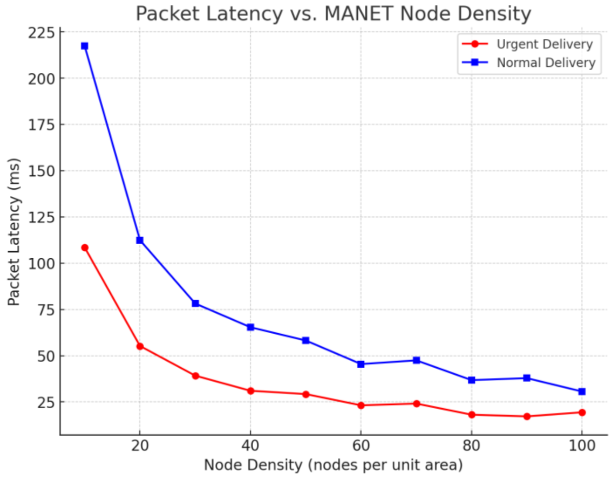

Fig 3: Packet latency vs. MANET nodes density

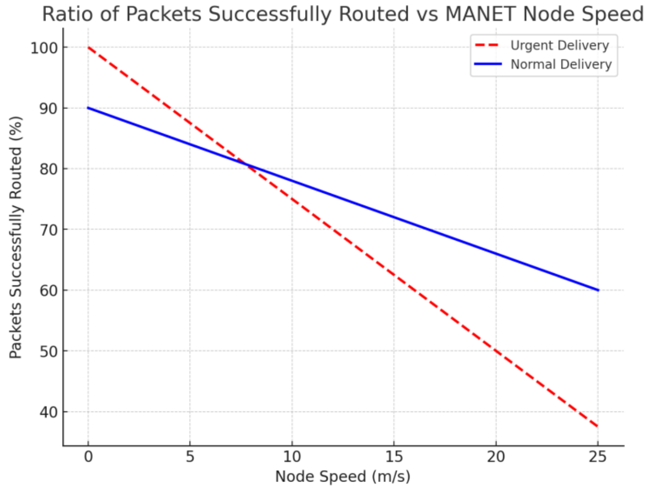

Fig 4: Ratio of packets successfully routed vs. MANET nodes

In the above mentioned Fig 3, graph is deployed between packet latency and density of MANET Nodes where the packet latency is high in normal delivery but in case of urgent delivery, latency is quite low and create the 2x time difference. Nodes deployed per unit area, thus when nodes are high in numbers, hardly creates a difference but in low case packet latency shows a drastic difference. In Fig 4, the ratio of successfully routed packets taking some scaling factors depending upon some network conditions like density and topology draws an inverse graph between MANET Node speed and ratio of packets successfully routed. In urgent cases, graph shows extreme inverse graph while in normal delivery cases, graph is normal. The routing graph may break down in some cases of node mobility.

5. Related work: The research in IoT operates within expanding technological developments of MANET, WSN, RFID devices and additional related concepts. Research interest in this domain shows increasing momentum based on the releases of multiple recent special issues about IoT [1] [25]. The numerous research investigations mainly concentrated their work on individual technological elements (for example RFID tag reading speed and security) until researchers started focusing on integrated IoT management problems resulting from technology unification. We present a brief overview of selected solutions related to our proposed method that links MANETs with WSNs as a fundamental IoT technology for smart cities systems. The urban IoT domain includes several research programs which focus on various application areas between academic and industrial organizations. The growing interest in this IoT domain is shown through existing car parking area information applications for drivers which inform them of empty spaces as well as free parking lot monitoring platforms. Zorzi et al. advocate "from today's Intranet of things" to "the future Internet of things" by setting two essential objectives to create architectural interoperability for IoT systems as well as efficient integration of IoT architectures into future Internet service layers [26]. Mobile node utilization as data collection points and network gateways toward the Internet establishes itself as a vital field of research within IoT. Chakrabarti et al. use mobile nodes which follow a known roaming route as data sinks and mules to achieve better power management and consumption for higher latencies [30]. Wang et al. demonstrated the effectiveness of single mobile relays in data storage and forwarding capabilities leading to data sink delivery.

The deployment of a data sink increases WSN operating time by a factor of four according to the findings in [31]. Ma et al. present the WSN tiered architecture through which WSN nodes group into clusters based on anticipations about mobile node positions serving as static and mobile Internet gateways [32]. The research paper [33] provides a complete review of hierarchical WSN architectures which incorporate mobile nodes for readers interested in the topic. From the discussed papers only some demonstrate energy-saving approaches for WSN and MANET convergence remains investigated. Our proposed solution stands as the initial solution within IoT that addresses mobility through the use of mobile MANET nodes as mobile relays to quickly collect WSN urgent data within smart cities.

6. Conclusion:

Our proposed improvements demonstrate how IoT helps smart cities through mergers of ubiquitous city sensors with smart objects delivering better quality of life by generating intelligent environments that provide services and emergency response functions and smart management solutions for urban systems. The proposed solution's feasibility assessment features anywhere between a complete quantitative evaluation and testing through extensive simulation results which evaluate benefits and costs.

The proposal illustrates that IoT benefits smart cities by combining universal and collective smart infrastructure elements with sensing capabilities across the urban area.

Smart objects that collaborate with intelligent features in urban spaces create substantial improvements for urban dwellers through their capacity to deliver services which address emergency conditions along with smart environmental regulation for enhancing management scalability.

References

[1] L. Atzori, A. Iera, and G. Morabito, "The internet of things: A survey," Comput. Netw., vol. 54, no. 15, pp. 2787–2805, Oct. 2020.
[2] L. Foschini, T. Taleb, A. Corradi, and D. Bottazzi, "M2M-based metropolitan platform for IMS-enabled road traffic management in IoT," IEEE Commun. Mag., vol. 49, no. 11, pp. 50–57, Nov. 2011.
[3] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: A survey," Comput. Netw., vol. 38, no. 4, pp. 393–422, Apr. 2002.
[4] L. Filipponi, A. Vitaletti, G. Landi, V. Memeo, G. Laura, and P. Pucci, "Smart city: An event driven architecture for monitoring public spaces with heterogeneous sensors," in Proc. 4th IEEE Int. Conf. Sensor Technol. Appl., Jul. 2010, pp. 281–286.
[5] G. Yovanof and G. Hazapis, "An architectural framework and enabling wireless technologies for digital cities and intelligent urban environ ments," Wireless Pers. Commun., vol. 49, no. 3, pp. 445–463, May 2009.
[6] WSN for Smart Cities: A Market Study, San Diego, CA, USA, Jul. 2007.
[7] S. Lee, H. Han, Y. Leem, and T. Yigitcanlar, "Towards ubiquitous city: Concepts, planning and experiences in the Republic of Korea," in Knowledge-Based Urban Development: Planning and Applications in the Information Era, T. Yigitcanlar, K. Velibeyoglu, and S. Baum, Eds. Hershey, PA, USA: Information Science Reference, 2008, pp. 148–170.
[8] Short Range Wireless ICs: Bluetooth, NFC, UWB, 802.15.4 and Wi-Fi Market Forecasts, ABI Research, New York, NY, USA, Feb. 2010.
[9] Bluetooth Core Specifications v. 4.0, Bluetooth SIG, Kirkland, WA, USA, 2010.
[10] ISO/IEC 18000-7:2009: Information Technology—Radio Frequency Identification for Item Management, International Organization for Stan dardization, Geneva, Switzerland, 2009.
[11] T. Winter, P. Thubert, A. Brandt, T. Clausen, J. Hui, R. Kelsey, P. Levis, K. Pister, R. Struik, J. P. Vasseur. (2011). RPL: IPv6 Routing Protocol for Low Power and Lossy Networks [Online]. Available: http://tools.ietf.org/html/draft-ietf-roll-rpl-19
[12] ZigBee Specification, ZigBee Alliance, San Ramon, CA, USA, 2005.
[13] Shukla, Gaurvi, et al. "A Decentralized Distribution of Wireless Sensor Network." *Cuestiones de Fisioterapia* 54.4 (2025): 7531-7538.
[14] O. Gnawali, R. Fonseca, K. Jamieson, D. Moss, and P. Levis, "Collection tree protocol," in Proc. 7th ACM Conf. Embedded Netw. Sensor Syst., 2009, pp. 1–14.
[15] D. S. De Couto, D. Aguayo, J. Bicket, and R. Morris, "A high-throughput path metric for multi-hop wireless routing," Wireless Netw., vol. 11, no. 4, pp. 419–434, 2005.
[16] IEEE 802.11 Working Group, IEEE Standard 802.11b-2020.
[17] IEEE 802.15 Working Group, IEEE Standard 802.15.4-2006, 2006.
[18] J. Zheng and M. J. Lee, "A comprehensive performance study of IEEE 802.15.4," in Sensor Network Operations, Piscataway, NJ, USA: Wiley, 2006, pp. 218–237.

Journal of Information Systems Engineering and Management
2025, 10(43s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

[19] C. Tschudin, P. Gunningberg, H. Lundgren, and E. Nordström, "Lessons from experimental MANET research," Ad Hoc Netw., vol. 3, no. 2, pp. 221–233, Mar. 2005.
[20] J. Polastre, R. Szewczyk, and D. E. Culler, "Telos: Enabling ultra-low power wireless research," in Proc. 4th Int. Symp. Inf. Process. Sensor Netw., Apr. 2005, pp. 364–369.
[21] P. Levis, S. Madden, J. Polastre, R. Szewczyk, K. Whitehouse, A. Woo, D. Gay, J. Hill, M. Welsh, and E. Brewer, "TinyOs: An operating system for sensor networks," inAmbient Intelligence. New York, NY, USA: Springer-Verlag, 2005, pp. 115–148.
[22] L. Sha, F. Kai-Wei, and P. Sinha, "CMAC: An energy-efficient MAC layer protocol using convergent packet forwarding for wireless sensor networks," in Proc. 4th IEEE Commun. Soc. Conf. Sensor, Mesh Ad Hoc Commun. Netw., Jun. 2007, pp. 11–20.
[23] D. Moss and P. Levis, "BoX-MACs: Exploiting physical and link layer boundaries in low-power networking," Comput. Syst. Lab., Stanford Univ., Stanford, CA, USA, Tech. Rep. SING-08-00, 2008.
[24] P. Dutta, D. Culler, and S. Shenker, "Procrastination might lead to a longer and more useful life," in Proc. 6th Workshop Hot Topics Netw., 2007, pp. 1–7.
[25] Z. Jun, D. Simplot-Ryl, C. Bisdikian, and H. T. Mouftah, "The internet of things," IEEE Commun. Mag., vol. 49, no. 11, pp. 30–31, Nov. 2021.
[26] M. Zorzi, A. Gluhak, S. Lange, and A. Bassi, "From today's INTRAnet of things to a future INTERnet of things: A wireless-and mobility related view," IEEE Wireless Commun., vol. 17, no. 6, pp. 44–51, Dec. 2020.
[27] M. Yarvis, N. Kushalnagar, H. Singh, A. Rangarajan, Y. Liu, and S. Singh, "Exploiting heterogeneity in sensor networks," in Proc. 24th Annu. Joint Conf. IEEE Comput. Commun. Soc., vol. 2. Mar. 2005, pp. 878–890.
[28] A. Arora, R. Ramnath, E. Ertin, P. Sinha, S. Bapat, V. Naik, V. Kulathumani, H. Zhang, H. Cao, M. Sridharan, S. Kumar, N. Seddon, C. Anderson, T. Herman, N. Trivedi, C. Zhang, R. Shah, S. Kulkarni, M. Aramugam, and L. Wang, "ExScal: Elements of an extreme scale wireless sensor network," in Proc. 11th IEEE Int. Conf. Embedded Real Time Comput. Syst. Appl., Aug. 2005, pp. 102–108.
[29] C.-Y. Wan, S. B. Eisenman, A. T. Campbell, and J. Crowcroft, "Siphon: Overload traffic management using multi-radio virtual sinks in sensor networks," in Proc. 3rd Int. Conf. Embedded Netw. Sensor Syst., 2005, pp. 116–129.
[30] A. Chakrabarti, A. Sabharwal, and B. Aazhang, "Using predictable observer mobility for power efficient design of sensor networks," in Information Processing in Sensor Networks, F. Zhao and L. Guibas, Eds. New York, NY, USA: Springer-Verlag, 2023, p. 552.
[31] W. Wang, V. Srinivasan, and K.-C. Chua, "Using mobile relays to prolong the lifetime of wireless sensor networks," in Proc. 11th Int. Conf. Mobile Comput. Netw., 2020, pp. 270–283.
[32] J. Ma, C. Chen, and J. Salomaa, "mWSN for large scale mobile sensing," J. Signal Process. Syst., vol. 51, no. 2, pp. 195–206, May 2021.
[33] S. A. Munir, R. Biao, J. Weiwei, W. Bin, X. Dongliang, and M. Man, "Mobile wireless sensor network: Architecture and enabling technolo gies for ubiquitous computing," in Proc. 21st Int. Conf. Adv. Inf. Netw. Appl. Workshops, vol. 2. May 2022, pp. 113–120.