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Proliferation of Opportunistic Routing: A Systematic Review

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ABSTRACT Opportunistic networks (OppNet) a new paradigm emerges after the great advancement of wireless technology and MANETs (Mobile Ad-hoc Networks). Store-Carry-forward phenomena is used to route the messages in OppNets; therefore, it is called delay tolerant network (DTNs). OppNet is such a heterogeneous flexible network that works in hurricane affected regions and volcanoes environment. The objective of this article is to determine, evaluate, elect and synthesize all terrific quality research work on the basis of Research Questions (RQ) which is significant to use for opportunistic routing. Systematic literature review on state-of-the-art researches on routing protocols are presented with comparative analysis. To eliciting relevant work for review, advanced exploration is conducted on contrasting digital libraries. This work gives the opportunity to the readers to understand what has been done in field of Opportunistic Routing (OR), what parameters effect the performance of protocol, name of the organization; who works in this field. At last, issues, challenges, and upcoming future terms of this network are discussed.

INDEX TERMS Delay tolerant network, opportunistic network, routing protocols, wireless network.

I. INTRODUCTION

In Sparse network scenario, integration of heterogeneous devices in which nodes having different capacity and type can be communicated through Opportunistic network [1]. Security and confidentiality contest becoming resilient as transmission and computing system are become more ubiquitous. Opportunistic network and Traditional network both are different from each other. Before data forwarding end to end path (source to destination) must be established in traditional routing. But in opportunistic network, heterogeneous devices (network nodes) are not directly employed, first they invited to join as seed node and this seed node becomes a helper node after performing a fixed task. Seed opportunistic network grows into an extended Opportunistic Network by merging helper's node in network [2]. Some properties of opportunistic network are: required immense substitutability, in worst case a single node (seed node) can start a network, highly multifarious software and hardware components are needed, When network is established, reliable connectivity is maintained between nodes, very rare to exist a complete path between source and destination because of separation of network into various regions, Store-Carry-Forward approach is used for message transferring between nodes, Highly temperamental tie-up performance because of wireless nature of network [2]–[4].

In the routing of Opportunistic Network (OppNet), it uses communal cellular medium as an opportunity instead of its obstacle. Because of broadcast nature of wireless medium, it reduces the limitation of irregular Wi-Fi transmission, is the basic key principle behind the opportunistic routing. Multiuser diversity property is used by opportunistic network, in which multiple neighbors overheard a data packet that is broadcasted by opportunistic routing [7]–[9]. OppNet is applicable in all emergency application like restoration from cyclone misadventure, providing internet to rural area [5], and homeland surveillance and trade organization [6]. Figure 1 shows the infrastructure of opportunistic network, which includes seven services. The description for the services is explained in table 1.

To accomplish the objective of systematic literature review (SLR), this paper includes effective routing protocol,

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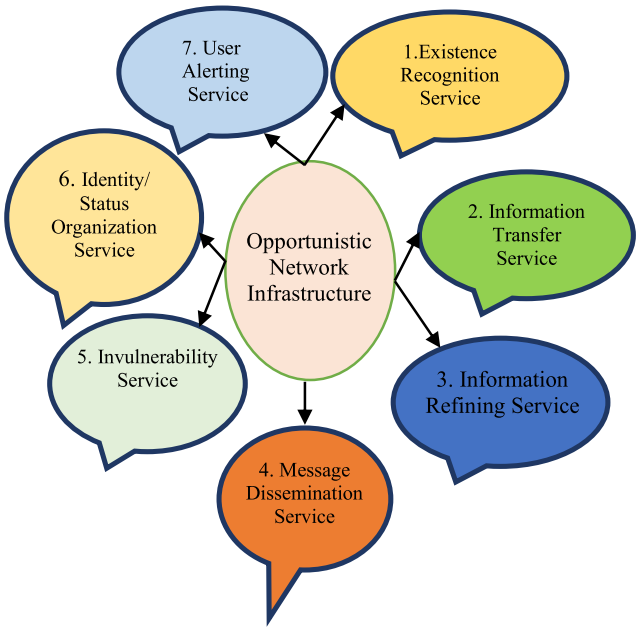

FIGURE 1. Infrastructure of opportunistic network.

TABLE 1. Seven layer services for oppnet.

S. No	*Services*	*Description*
1	Existence Recognition Service	It gives knowledge/details about the presently active nodes or user those are in dissemination range and wants to participate in network.
2	Information Transfer Service	Sending and receiving of information within one hop communication is done by this phase. Assurance of error free and eminent information released at sender is not provided by this phase.
3	Information Refining Service	In the network, this step is used to avoid the hazard of illegitimate action
4	Message/information Dissemination Service	Various options are existing for the user/node like benefit the accepted message or deportation or contribute (transfer) to alternatives node or/either collect the message and directly pass it on the other nodes, which is in contact spectrum.
5	Invulnerability Service	This service provides to make data/information secure, integrated and authenticated during changeover from one hop to other.
6	Identity/status organization service	In this organization service, node work as an unidentified manner or with authorize identification. This service defines how a node shows in the network. Factious identity must be avoided in network, is ensured by this service
7	User Alerting Service:	This service immediately announces to the node about incoming information that needs quick reaction. Information precedence like low, medium or high according to the demand of service is given by this step [9].

present in interdisciplinary researches. Section II describes strategy used for conducting SLR. Systematic review results presented in section III. Analysis and factful review, with their comparison are discussed in section IV. Section V illustrates the discussion on RQ. Overall discussion on this SLR is briefed in section VI. Finally, section VII concludes the paper.

II. SYSTEMATIC REVIEW PROCESS

In prevailing proliferation, diverse types of literature study have been carried out in field of Opportunistic Routing (OR). Many researchers proposed their work and provides reliable routing in network. On the basis of optimization, link-state, probabilistic, geographical, and etc., researcher introduced the efficient protocol. Multifarious authors reviewed existing protocol on the basis of their chronological order, quality, characteristics, limitations, and etc. After extent of our searching procedure, no SLR has been conducted on OR. This article presents the SLR on existing routing protocols in OR, it pursues the systematic review procedure used by Kitchenham *et al.* [10]. This section describes the following subsections like; formation of leading research questions, procedure used for search, inclusion-exclusion benchmark to find suitable article, and formulation of quality estimation criteria.

A. RESEARCH QUESTIONS

Formation of leading research questions is the most difficult and important step of systematic literature study. The primary aim of this SLR is to provide answers of research questions presented in table 2.

B. SEARCH PROCEDURE

To accomplish the terrific SLR, research articles from the most reputed journals are included from digital database. Table 3 shows the list of data sources with their links. International conferences, journals, books, and thesis related to OR are also consulted in this work. Many key-terms were searched during identifying research questions such as ''wireless network'', ''delay tolerant network'', ''opportunistic network'', ''routing'', ''protocols'', and ''opportunistic communication''. Abbreviations and synonyms of these key-terms were also used during search process of articles. All key-terms are not case-sensitive. Logical Boolean OR, AND, and NOT operators with key-terms were used to identify suitable research paper.

C. INCLUSION EXCLUSION BENCHMARK

Wireless network with their routing protocol were focused in this study. Research articles published from 2003 to 2021were considered, which includes the one or more key-terms related to OppNet, protocols, security, parameters, delay tolerant network, tools, and opportunistic communication. Peer-reviewed articles, conference paper, journal paper, and newsletter were part of this SLR. Title-based, abstract-based, content-based, quality-based, and reference-based papers are included to find the relevant answers of research questions. The research

TABLE 2. Research questions (RQ).

RQ:1	How routing works in OppNet and how it is different from routing in MANET? *Purpose:* To understand the basic routing procedure in both the wireless network.
RQ:2	What are the contrasting categories are available in OR and which protocols are exist in which category? *Purpose:* To determine the current and previous work done in the field of opportunistic routing. Also helps the researchers to work in their search area.
RQ:3	What are the imperative network parameters/ factors to provide secure and reliable routing? *Purpose:* This question provides the desired information and rational meaning of the network metrics used in network. Researchers can be considered these parameters during design of their novel protocol.
RQ:4	What are the existing applications and companies in the area of OppNet? *Purpose:* This work determines the real-life based applications and companies in the field of opportunistic networks.
RQ:5	What is the importance of this SLR for the researchers in the field of OR? *Purpose:* It gives basic as well as advance information to the authors in the area of OR.
RQ:6	What are the dominant issues, challenges, and future terms in OppNet? *Purpose:* Current dominant issues while making protocol, their challenges, and future terms could be used in OppNet are elaborated. It encourages authors to work in desired direction.
RQ:7	What are the available tools for simulating the wireless network? *Purpose:* To provide all the relevant information in-context to simulation tool with their comparison are provided in this question, which helps researchers to use appropriate tool for their proposed work.

papers were excluded if they exist in one or more of the following traits:

i. Research articles which work only for theoretical model and not been simulated/implemented on any tool were excluded in this SLR.
ii. Duplicate papers on the basis of their title, abstract, content, and name of routing protocol were not included in this work.
iii. Research papers that were not published by reputed journal/conferences were also eliminated.
iv. Those papers were extracted, which not include the key-terms (discussed in earlier section).
v. Papers having the language other than ''English'' were not considered.

D. QUALITY ESTIMATION CRITERIA

This section describes the quality estimation criteria to calculate quality of each research article. Outcome from the article, effectiveness of the article evidence, and level of systematic bugs free document (in terms of layout) are the factors on which quality of the papers depends. According to reliability of the article and level of satisfying the QE criteria; each paper is designated as satisfied (S), not satisfied (NS), and partially satisfied (PS).

TABLE 3. Selected data sources.

S. No.	Data Source	Category	URL Link	No. of Searched Articles
1.	Google Scholar	Search Engine	http://scholar.google.com	156
2.	Association of Computing Machinery (ACM)	Digital Library	http://dl.acm.org/dl.cfm	132
3.	Institute of Electrical and Electronics Engineers (IEEE)	Digital Library	http://ieeexplore.ieee.org/Xplore/	117
4.	Web of Science	Digital Library	http://www.webofscience.com	120
5.	Scopus	Digital Library	http://www.scopus.com	129
6.	Elsevier	Digital Library	https://www.elsevier.com	126
7.	Springer	Digital Library	http://link.springer.com/	128
8.	Science Direct	Digital Library	http://www.sciencedirect.com	119
9.	Wiley	Digital Library	http://onlinelibrary.wiley.com/advanced/search	188

TABLE 4. Quality estimation criteria (QE).

QE:1	**Is the title of the article being adequate and unambiguous?**
QE:2	Is the article cover all their objectives which stated in abstract section?
QE:3	Are the paper focuses on real issues that exist in environment?
QE:3	Is the related work adequately included in paper, which is relevant to their particular domain?
QE:4	Is the paper successfully resolve the issues, that were stated in the objective?
QE:5	Is the performance of the method successfully verified and compared?
QE:6	Is the discussion section present in the article?
QE:7	Are the future directions in their domain is mention in the article?
QE:8	Are the references cited correctly in the document?
QE:9	Is the paper useful for real life applications/ future research?

Table 4 shows the set of QE questions; on which each article was evaluated. Set of QE is consisting with nine questions. Every research paper was scored as 1,0, or 0.5 against each QE; thereafter score was calculated. At last, the articles whose score is greater-than 4 were included in this study. Procedure of assigned the quality score to each paper were the complicated task and this score may be varied according to the evaluator. After searched the inclusion-exclusion standard and quality estimation question, it was necessary to collect the data & analyze this data to find out the aforementioned estimation questions. Title, author's name, problem statement, source (conference or journal), method, pros, limitation, conclusion and future directions, and etc., information were extracted from the articles.

III. SYSTEMATIC REVIEW RESULTS

Recognition, extraction, acceptance, and inclusion were the four phases through which this SLR was carried out. Each phase of SLR were further classified into diverse sub-phases, like extraction phase was sub-divided into title-based, identical article-based, and abstract-based extraction. The primarily objective of these extraction were only to find the suitable and to provide the answers of RQ (from table 2). The procedure for systematic literature study is depicts in figure 2, and illustrated as follows:

A. RECOGNITION/IDENTIFICATION PROCESS

Initially 1215 research papers were searched out from the various digital databases like; google scholar, ACM, IEEE, springer, Scopus, Elsevier, Web of Science and etc. Table 3 described the number of papers retrieved from these databases. This is the first phase of conducting SLR, thereafter these articles were examined in next process.

B. SCREENING/EXTRACTION PROCESS

In this stage process; first we excluded the article on the basis of their "title". Unambiguous, unclear, not relevant to our concerned field, and etc. traits were applied to eliminate the papers on the basis of title. 355 articles were found relevant out of 1215 and 860 articles were not considered on the basis of their title. Secondly; 56 articles were excluded on the base of their identical copy. Only 299 articles were found.

C. ACCEPTANCE/ELIGIBILITY PROCESS

After extracting the articles at the stage of screening, it is essential to accomplish the phase of acceptance/eligibility. This phase of SLR is most crucial and time-consuming due to detail study of each article. On the basis of full-content of the paper, specifically 65 articles were considered at this level. 91 articles were rejected at the completion of this phase. After explored the 65 articles, 12 more articles were found desirable from the reference section. Now, 77 research articles were eligible after successful completion of this phase.

D. INCLUSION PROCESS

This is the last phase of SLR, quality estimation criteria (from table 4) were utilized to evaluate the quality of 77 articles. Only 65 articles were found suitable in inclusion process. Any conflict related to the election or rejection of the article were solved by the conversation between authors.

IV. ANALYSIS AND FACTFUL REVIEW

A. ANALYSIS AND FACTFUL REVIEW

The comparative analysis and detailed review of considered studies are presented in table 5. The term I described as implementation for proposed work either as Theoretically (TH)/Mathematically (M)/Tool (T).

V. DISCUSSION ON RESEARCH QUESTIONS

After illustrating the analysis and review of Opportunistic routing, this section addresses the RQ from table 2.

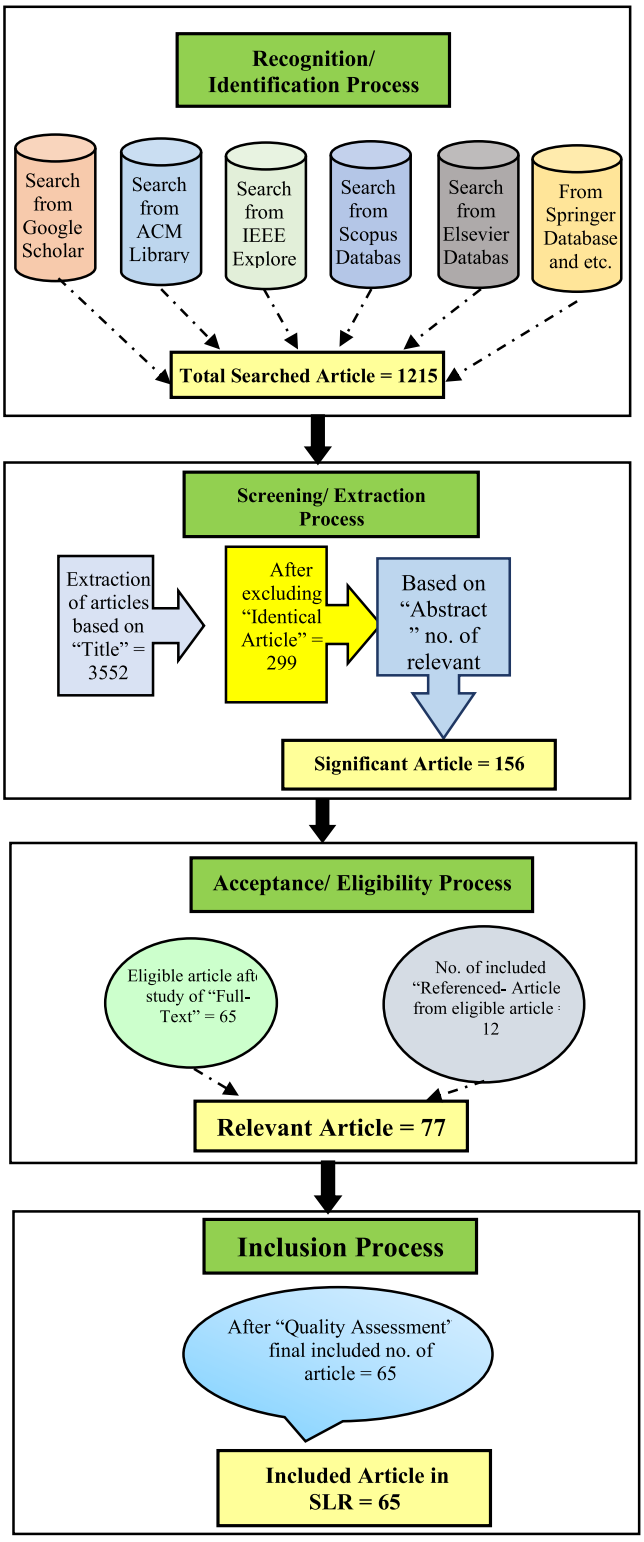

FIGURE 2. Procedure for systematic literature study.

RQ:1 How routing works in OppNet and how it is different from routing in MANET?

Ans: In wireless network (MANET) routing all mobile nodes (MN) are connected through wireless link and source node (S) transmits the packet to destination node (D) by

TABLE 5. Comparative studies of selected articles in SLR.

Article-id	Year	Author Name	Category	Name of the Protocol	Focus Region	Methodology	Future Area	I (TH/M/T)	Citation - Score	QA Score (out of 9)
A-1	2005	S. Biswas et al. [27]	Link State Aware (LSA)	Ex OR	Improvement in Throughput as compared to single path traditional routing.	TDMA based MAC Scheduling. Long radio links with high loss rates.	Deterioration of Duplication of packets.	T (38-node 802.11b test bed)	1957	8.5
A-2	2007	S. Chachulski et al. [31]	LSA	MORE	Designed low-complexity algorithm to improve throughput with 22% w.r.to Ex OR.	Integration of OR and Intra-Flow Network Coding. Not used medium access scheduler.	Elimination of batch-limit, duplicate packets. Enhancement in scalability.	T (20-node wireless test bed)	1592	9
A-3	2008	D. Koutsonikolas et al. [35]	LSA	XCOR	Improved throughput by 34%, 115% as compared to OR, traditional routing respectively.	Interflow network coding with opportunistic routing.	Evaluation of this protocol in large network with different pattern & topology.	T (QualNet)	36	6.5
A-4	2008	Y. Lin et al. [32]	LSA	Code OR	Minimization of batch-limit problem. 5 times increased throughput as compared to MORE.	Multiple segments can be sent concurrently in network. End-to-end (E-ACK) & hop-by-hop acknowledgment (H-ACK) is used.	Only work with low to medium packet size; how it can work with large packet size.	TH & T (customized discrete event simulator)	203	8
A-5	2009	C. Hsu et al. [28]	LSA	ECONOMY	100% network throughput provided with elimination of packets replication.	ETX matrix is used. Token passing scheduling approach.	How it can used with multiple flow and mobility scenario.	T (QualNet)	40	5
A-6	2010	Y. Lin et al. [34]	LSA	Slide OR	Minimize the complexity to schedule multiple segments to improve throughput as compared to MORE.	Encoding of source packets in overlapping sliding window which is useful at decoding time.	How it can work with large window size.	T (discrete event simulator)	124	7
A-7	2010	D. Koutsonikolas et al. [36]	LSA	CCACK	Reduction in duplicate packets. 45% improved throughput as compared to MORE.	Null Space based ACK is used with NC. Efficient credit-based, rate control algorithm.	Can also be validate through other tools.	TH & T (Glomosim)	222	8

TABLE 5. *(Continued.)* **Comparative studies of selected articles in SLR.**

A-8	2011	M. K. Han et al. [37]	LSA	O3	Election of coded packets.	Jointly optimize opportunistic path with rare limits, inter & intra-flow coding.	Evaluation of wireless, and real-time application.	T (QualNet)	34	5
A-9	2003	H. Fussler et al. [25]	Geographical OR (G-OR)	CBF	Reduces the wireless channel load to improve delivery ratio.	Position-based timers used. Single-hop packet transmission, contention period, and suppression; 3 steps of CBF.	Reduction of delay time. Can use MAC layer to avoid hidden terminal issue.	T (NS-2)	605	9
A-10	2003	M. Zorzi et al. [22]	G-OR	GeRaF	Collision avoidance protocol is established to increase latency & energy.	Used the hypothesis of Poisson Distribution.	Improvement in delay & energy.	M & C++	1596	8
A-11	2005	Y. Yuan et al. [17]	G-OR	ROMER	High rate of packet transfer, and minimize error rate against lossy link.	Random selection of relay node with flexibility.	How it can work in terms of security.	T (NS-2)	190	7.5
A-12	2007	K. Zeng et al. [23]	G-OR	GOR	Evaluation of one-hop & path throughput. Trade-off between packet advancement, transmission reliability, and medium time delay.	Heuristic candidate selection algorithm. Assign the priority of packets.	How it can work with multiple channel rate.	T (GloMoSim)	126	9
A-13	2007	M. Nassr et al. [18]	G-OR	DTRP	High packet transfer in medium & large network.	Probability assigned to relay node according to distance between source & receiver node.	Evaluation on energy used factor.	T (MICA-2 testbed)	64	8
A-14	2008	K. Zeng et al. [33]	G-OR	MGOR	Eliminate the weakness of GOR (single channel rate), it Support multiple channel rate.	Heuristic candidate selection algorithm to select, prioritize, and coordination of relay node.	Enhancement in scalability.	T (GloMoSim)	93	8
A-15	2009	S. Yang et al. [38]	G-OR	POR	Effective packet transmission.	Multicast location-based information.	Removal of duplicate packets.	T (NS-2) & TH	74	8.5
A-16	2012	Z. Wang et al. [39]	G-OR	CORMAN	Improved packet delivery ratio with throughput gain.	Path computation, and routing-based decision between node done by RSSI.	Communication in multi-hop.	T (NS-2)	196	9

TABLE 5. *(Continued.)* **Comparative studies of selected articles in SLR.**

A-17	2006	J. Burgess et al. [41]	Probabilistic OR (P-OR)	MaxProp	Packet scheduling to maximize delivery rate & minimize latency.	Probabilistic approach with the integration of routing protocol & scheduling.	How it can work with real time application.	T (UMassDieselNet-customized simulator)	2713	9
A-18	2008	J. L. V. Conan et al. [42]	P-OR	FPOR	Reduces packet delivery time. Loop-free protocol with polynomial time converge.	Random, Exponential and Poisson probability distribution method used for fixed point of recursive routing.	How it can work with real dynamic network.	T (Simulated with Dartmouth, iMote, MIT data set used)	138	7.5
A-19	2008	A. C. V. Erramilli et al. [44]	P-OR	Delegation Forwarding	Selection of relay node which, gives high performance with low cost.	Encounter time with optimal stopping to elect relay node.	Effectively use of bandwidth & storage resources.	T (real-mobility traces-simulator)	267	7
A-20	2009	S. Nelson et al. [45]	P-OR	FBR	Maximize packet delivery & decay in production of duplicate packets.	Quota-based protocol. Exponentially weight moving average scheme is used to calculation of encounter value.	How can apply probabilistic splitting rule. Effect of using 2nd order derivative.	T (ONE)	556	8.5
A-21	2009	C. Liu et al. [46]	P-OR	OPF	To increase delivery probability. OPF matric is utilized.	More than one relay node is used. Optimal stopping rule is used.	Ticket-based & broadcast forwarding. Backward induction method.	T (UMassDieselNet-customized simulator)	120	9
A-22	2003	Z. Zhao et al. [56]	Cross layer-PHY-Aware (C-PA)	TLGOR	Increased in QoS, QoE, PDR, and SSIM.	Link quality, energy, weighted sum of progress metrics value is used to select relay node.	Reduction in interference level in large network.	T (OMNet++)	603	9
A-23	2010	A. Bletsas et al. [47]	C-PA	ILOR	Work with low delay in noise & interference-limited environment.	Dissemination PHY-Aware reactive relay selection approach. Relay node is elected by calculating their RSSI.	Analyze the effect of slow-fading & dense network.	M	94	7.5
A-24	2011	G. Lee et al. [48]	C-PA	SPOR	High throughput with considering link level interference. Resilience performance in 1-D network model (up to 4 hops).	Long-haul path is used to improve delivery rate. Removal of duplicate packets.	Analyze the performance in multidimensional network model.	M & T	26	6
A-25	2011	X. Mao et al. [49]	C-PA	EEPOR	Election & prioritization of relay node with effective energy consumption.	Optimum algorithm for adjustable & non-adjustable transmission model.	Effect of interference factor.	T (TOSSIM)	310	6.5

TABLE 5. ***(Continued.)*** **Comparative studies of selected articles in SLR.**

A-26	2013	W. Y. Shin et al. [50]	C-PA	Parallel OR	Improvement in network throughput. Concurrent flow of packets in huge network. Avoid inter-node interference.	TDMA approach is used to disseminate the packets. Relay node is used on the basis of SNIR.	Analyze the effect of signal overhead.	M	9	7
A-27	2010	M. N. R. Bruno et al. [51]	Cross layer MAC-aware (C-MAC)	OSPR	Concurrent flow of packets. Improvement in γ factor to enhance the routing efficiency.	Integrates packet scheduling with OR. Throughput gain metric is used to select relay node.	Analyze the effect in large network.	T	17	7
A-28	2011	B. Pavkovic et al. [52]	C-MAC	ORPL	Increment in energy efficiency. Enhanced load balancing, node fairness, and data assembling features.	IEEE 802.15.4 standard cluster tree architecture is used for routing. ETX value is used to select relay node.	Evaluation of the effect of limited buffer size & high traffic loads.	T (customized discrete event simulator)	96	6
A-29	2013	S. Duquennoy et al. [53]	C-MAC	S-ORPL	Focus on low energy consumption, robustness, scalability, and latency.	EDC metric and knowledge of neighbor sub-tree is used to elect relay node.	Analyze the optimization of CRS.	T (Contiki OS)	185	7.5
A-30	2014	E. Ghadimi et al. [59]	C-MAC	ORW	Work in dense network with maximize energy efficiency & minimum delay.	Distributed algorithm is used to find EDC value for relay node. Low power observes and asynchronous duty cycle used by sensor node.	Effects of high throughput setting.	M & T (Monte-Carlo Simulation)	113	8
A-31	2009	M. Lu et al. [54]	Cross layer Hybrid (PA-MAC)	PRO	Improved throughput in under fading and user mobility. Works well with 802.11 standard and WMN.	PHY, MAC, and network layer information. Transitory link quality evaluation process is used to select relay node.	Analyze the effect in scalable network and other simulator.	T (FlexMAC)	113	8.5
A-32	2014	J. Zuo et al. [55]	PA-MAC	CLEE	Maximized throughput with reduced energy utilization as compared to EEOR.	Information of relay node, FER, and packet retransmission from MAC layer.	How it works in dynamic large network.	M & T	62	8
A-33	2014	Z. Zhao et al. [56]	PA-MAC	SCAD	Selection of relay node based on real time traffic load & energy drain rates.	Various cross-layer content information is used. DFD timer merged with receiver node.	Evaluation with spatial diversity & MAC approach.	T (WISEBED testbed)	4	6
A-34	2009	R. Laufer et al. [61]	Optimized- Graph based (O-GBR)	SMAF & MABF	Optimal relay selection with using hyper-graph. Minimize the EATT factor.	Abstraction of Dijkstra and Bellman Ford unique path routing algorithm to any path routing.	Evaluate also with factors like packet drop, delay, overhead, and etc. Can also simulate in other tools.	M & T (802.11b test bed)	155	8.5

TABLE 5. ***(Continued.)*** **Comparative studies of selected articles in SLR.**

A-35	2011	R. Laufer et al. [58]	O-GBR	PLASMA	High throughput with minimum delay.	Polynomial-time dispersed algorithm PBF is used to estimate transfer rate, candidate relay sets and gateway subgroup that reduces the routing cost	Effectively use of resources and node fairness. How it can applicable with hotspot.	T (802.11b test bed)	55	7
A-36	2013	Y. Li et al. [60]	O-GBR	LOR	Can work in large network. Minimized time complexity.	Using graph theoretical approach. Balance between CRSs and scalable routing.	Analyze of E2E delay, and energy utilization in large scale OR.	T (NS-2)	38	6.5
A-37	2013	X. Fang et al. [62]	O-GBR	MAP	High throughput with low energy and minimum delay. Solve the NP-hard OMCAP problem.	Used Dijkstra algorithm, polynomial-time algorithm to calculate K-approximation.	Can be implement on simulation tools.	M	20	7.5
A-38	2008	J. Wu et al. [63]	Optimized- Utility based (O-UOR)	OPRENU	To improve packet delivery and reliability by opportunistic relay.	Concept of optimal & heuristic is used to elect relay and determine the priority of relay nodes.	Evaluate the impact of transmission. How it works in multi-path with network coding.	T (NS-2)	98	8
A-39	2008	X. Zhang et al. [64]	O-UOR	DICE	To enhance efficiency-fairness tradeoff, for cooperative and selfish users in multi-path network coding.	Nash bargaining solution for cooperative user & socially optimal solution for selfish user.	Analyze the performance on other simulator with parameters like: E2E delay, Overhead ratio, and etc.	T (Drift Emulator)	104	9
A-40	2011	X. Fang et al. [69]	O-UOR	CONSORT	Solve the problem of resource allocation with multiple users.	Designed distributed algorithm by integrating primal-dual & sub gradient method.	Evaluate the performance with scalability.	M & T (discrete event simulator)	32	6.5
A-41	2013	M. Xiao et al. [65]	O-UOR	TOUR	Reduced delay & cost with high delivery probability.	Used time-sensitive utility model.	How to reduce the cost in high utility.	T (real trace-driven simulator)	68	7
A-42	2011	A. Bhorkar et al. [66]	Optimized- Learning based (O-LOR)	Adapt	Solve the issue of learning & routing in opportunistic context. stochastic approach that optimally explores & exploit the network opportunity.	Reinforcement learning is used without the information of channel and network model.	How to control congestion with high throughput.	T (802.11b & QualNet)	102	9

TABLE 5. *(Continued.)* **Comparative studies of selected articles in SLR.**

A-43	2013	P. Tehrani et al. [67]	O-LOR	ORL	Selection of relay node in unknown probabilistic local broadcast model.	Dynamic distributed & centralized learning algorithm is proposed.	Analyze the performance on tool & compare with protocols.	TH	10	6.5
A-44	2019	G. Dhand et al. [70]	Security (S)	SMEER	Focused on efficient routing with energy utilization.	Used Elliptical Curve Cryptography (ECC).	How to enhance in terms of dense & delay in network.	T (NS-2)	16	7
A-45	2020	S. K. Dhurandher et al. [71]	S	MT-SMRP	Provide trust & encryption by proposed secure multipath routing protocol.	Trust, acknowledgement, encryption/decryption mechanism are proposed.	Evaluate the performance on real mobility traces.	T (ONE)	6	8
A-46	2020	D. K. Sharma et al. [72]	S	ETSP	Aim to identify black-hole attack.	Prophet routing is used.	How to detect change behavior of nodes.	T (ONE)	3	7
A-47	2021	S. Rashidibajgan et al. [73]	S	Secure & privacy routing	Provide framework to identify sybil, and malicious behavior in network.	Cooperation method, and shared public key is used to hide location.	How to minimize the cost with detection of attack.	T (ONE)	0	7
A-48	2007	Boldrini et al. [74]	Context-based (CB)	HiBop	To efficiently use of buffer space & handle network traffic.	Context information & identity table is used.	To achieve fine-grain control and analytical bound calculation.	T (custom simulator with community-based data model)	364	5
A-49	2009	Niu et al. [75]	CB	Community Data	To increase data delivery ratio.	Replication-based data broadcast scheme is used.	How to work in dense network.	T (ONE)	38	4.5
A-50	2003	Lindgren et al. [77]	CB	PROPHET	To increase delivery probability.	Encounter history & transitivity.	How it can proved theoretically & reduce overhead ratio.	T (ONE)	3069	6
A-51	2007	Daly et al. [78]	Social-Aware (SA)	SimBet	To achieve reduced delivery data & overhead ratio.	Centrality & Similarity metrics are used to calculate social information of the nodes.	How to reduce complexity.	T (real trace-driven simulator)	1613	8.5
A-52	2010	Mtibaa et al. [79]	SA	People Rank	To provide the balance between duplicate messages and delivery probability.	Web page indexing of Google scheme is used to rank the node in the network.	How to provide security against attack in network.	T (real mobility trace-driven simulator)	412	8
A-53	2008	Hui et al. [80]	SA	Bubble Rap	To achieved high delivery probability with minimum overhead ratio.	Community-based local & global rank to each node is given to provide communication.	How to work in highly dynamic network.	T (HaggleSim Emulator)	2691	8.5
A-54	2012	Spachos et al. [81]	Energy-based (EB)	EAOR	To maintain QoS with minimum energy consumption.	For routing distance-based formula is used. RTS, CTS, DATA, and ACK four type of packets are used.	How to minimize complexity.	T (OMNET++)	18	7.5

TABLE 5. *(Continued.)* **Comparative studies of selected articles in SLR.**

A-55	2009	Kim et al. [82]	EB	ORTR	To achieve high delivery probability with efficient transmission power in real-time network.	Heuristic function with the integrated features of MAC & Routing layer is used.	How it is applicable with real-time network.	T (NS-2)	43	7
A-56	2010	Yang et al [83]	EB	EARTOR	To maintain QoS with keep the trade-off between energy utilization & end-to-end latency.	Bidding approach on the basis of residual energy factor is used to elect relay node.	How to work with highly dynamic network.	T (MATLAB)	18	7
A-57	2005	Khaled et al. [84]	Flooding-based (FB)	Controlled Flooding	To maximize delivery with minimum flooding cost.	Probability, TTL, kill time of node is used to transmit packet.	How to transmit packet for multiple destination node.	T (GloMoSim)	316	6
A-58	2005	Spyropoulos et al. [85]	FB	Spray & Wait	To reduce duplicate packet during transmission	Broadcast limited no of packet in spray phase & then wait.	To maximize throughput.	T (discrete event simulator & M)	1598	7
A-59	2005	Spyropoulos et al. [76]	FB	Spray & Focus	To control duplicate message with minimum delay in network.	Forwarding tokens are used by sender node to transmit data packets.	How to increase delivery probability in large area.	T (discrete event simulator)	766	6
A-60	2003	Vahdat et al. [86]	FB	Epidemic	To reduce transmission delay.	Randomly transmit the packet, to ensure every node receives data packets.	To reduce duplicate no. of packets.	T (discrete event simulator)	5614	6.5
A-61	2005	Sharma et al. [87]	FB	PBFER	To reduce overhead ratio & latency.	Priority-based with FIFO scheme is used.	To minimize congestion in the network.	T (ONE)	9	5.5
A-62	2021	S. Banyal et al. [69]	Miscellaneous (M)	HiLSeR	Provides routing in Opp-IoT with high delivery ratio, and minimum energy.	Used 3-tiered clustering scheme to enable sectionalization and constrain flooding.	How to minimize computation cost.	T (ONE)	2	8
A-63	2007	Balasubramanian et al. [88]	M	RAPID	To reduce delay with high delivery ratio.	Message utility value is used in average delay matric to transmit packet.	How to minimize complexity.	T (customized discrete event simulator)	1372	8.5
A-64	2007	Ramanathan et al. [89]	M	PREP	To maintain high delivery ratio, when network load increases.	Prioritized scheme on the basis of packet's TTL value & present overhead cost is used.	How to work efficiently with limited buffer & bandwidth.	T (NS-2)	421	8
A-65	2021	Dalal et al. [90]	M	ORFP	To improved delivery probability, reduced overhead ratio & average hop-count.	Combination of random forest and firefly algorithm is used to select relay node.	How to work against malicious node.	T (ONE)	0	5.5

using appropriate routing algorithm [11]–[15]. Figure 3 shows the how routing work in wireless ad-hoc network. Figure 4 describes the Opportunistic network routing, where CRSs (candidate relay sets) is chosen to forward the packet from source node to destination node [16]. There are four basic steps to provide routing in DTN (Delay Tolerant Network): Determination of candidate relay set, Selection of optimum Relay and its declaration, Data transmission and recognition, and Handling of adaptive network by opportunistic routing [16].

Determination of candidate relay set includes: Exploring candidate relay, ranking of candidate relay by using metric, Enhancements of CRSs, and Refinement of CR (Candidate Relay).

Selection of optimum Relay and its declaration includes: Casting the relay; by probabilistic method [17]–[20] and by deterministic method [21]–[24]. Declaring relay by using coordination method. Coordination can be done by: Contention-based method [25], [26], Timer based method [27], Token based method [28], and Random based method [17].

Data transmission and recognition: to ensure reliability in transmission, ARQ process is implemented at link layer or network layer. ARQ process can be of receiver generates end to end acknowledged [29], [30], and forwarders generates hop-by-hop acknowledged [31], [32].

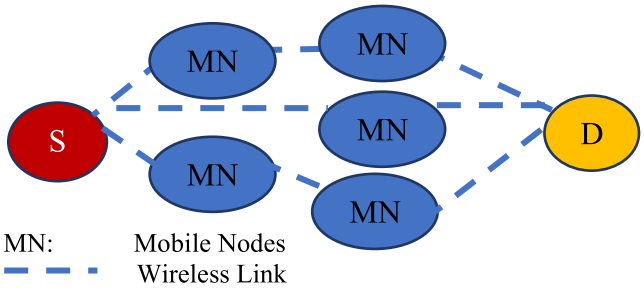

FIGURE 3. Routing in wireless network.

Handling of adaptive network by opportunistic routing: wireless network is adaptive because of diversity in wireless dissemination environment because of channel fading (affects reliability and quality) and movement of nodes that affects configuration of network. Table 6 describes the traits and differences between MANET and OppNet. It includes the diverse characteristics like nodes' movability, way of communication, size of network area and etc.

RQ:2 What are the contrasting categories are available in OR and which protocols are exist in which category?

Ans: It includes distinct types of categories like, link state aware OR, Geographic OR, Probabilistic OR, Cross layer OR (also expanded in PHY-Aware, MAC-Layer, and combination of PHY and MAC aware OR), Optimized based OR (includes Graph based, Utility based and Learning-based), Security-based, Context-based, and others as shown in figure 5.

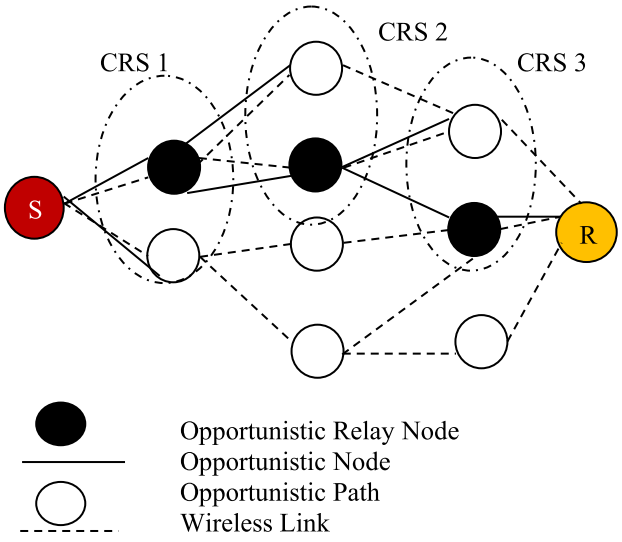

FIGURE 4. Routing in opportunistic network.

TABLE 6. Manet vs. OppNet.

Characteristics	MANET			OppNet		
Nodes' Movability	Yes			Yes		
Way of Communication	Synchronous			Asynchronous		
One-Hop/ Multi-hop	Multi-hop			One-Hop		
Co-ordination among Nodes	High			Low		
Bundle Layer	Not used			Used		
Store-Carry-Forward Principle	No			Yes		
Size of Network Area	Low	Medium	Large	Low	Medium	Large
	Yes	Yes	No	Yes	Yes	Yes

A. LINK STATE AWARE OR

It includes various different type of routing protocol as shown in figure 6 and their description are:

EX OR: First demonstration of opportunistic routing principle and infrastructure including MAC operation is done by EX OR protocol, proposed by Biswas *et al.* [27]. Throughput is enhanced by a factor 2-4 as compared to single path traditional routing. Time division multiple access (TDMA) based MAC scheduling procedure is used for forwarding a data packet by candidate relay. Drawback of EXOR, Imperfect link with candidate forwarder makes replication of data packet transmission in network.

ECONOMY [28] proposed by Hsu *et al.*, token passing scheduling is used for forward packets in network therefore strongly connected CRSs (candidate relay sets) are formed. So that it eliminates the problem of replication transmission. Pros: (a) network throughput is 100% improved as compared to traditional routing protocol. (b) ETX matrix is used (duplicate free). Cons: not suitable for multiple flow scenarios.

MORE: MAC independent Opportunistic Routing and Encoding proposed by Chachulski *et al.* [31]. First routing

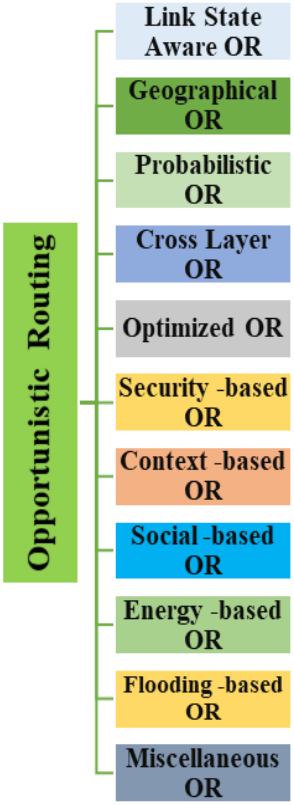

FIGURE 5. Opportunistic network routing categories.

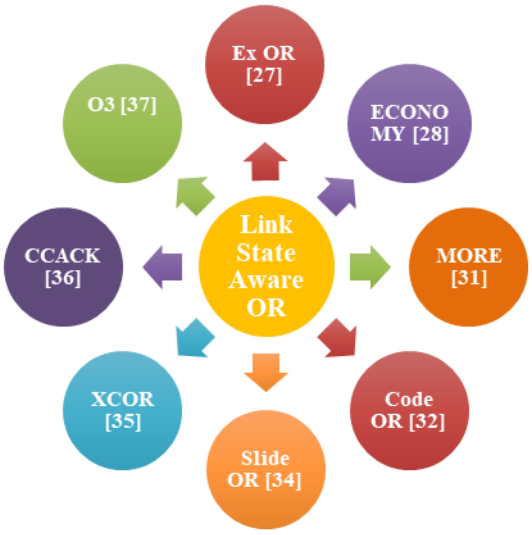

FIGURE 6. Routing protocols in link state aware OR.

protocol which integrates OR and Intra-Flow network coding (NC) as coordination method which enhance network end to end throughput. Initially original data packets are breaks into batches (have K packet in each batch). K original data packet in random linear combination is disseminated by sender node. After receiving and restoring original data packet from K linearly independent packet, receiver node sends ACK (acknowledgement) to sender node. Pros: increased throughput compared to traditional routing. Cons: duplicate packet transmission by relay and batch limit.

Code OR: Coding process in MORE introduced by Lin *et al.* [32]. Batch limit problem is reduced in code OR, because sender node can send sliding window of many segments. Packet coding for same block done by sender node is called segment in this protocol. Receiver node sends end to end ACK to sender node, after receiving a segment of data packet. After acquiring enough number of coded packets is in segment, intermediate node using Hop ACK to announce this information to its upstream. Code OR, five times better throughput as compared to MORE [31].

Slide OR: proposed by Lin *et al.* [34], it enhance network throughput by integrating various coded packet at different segment/sliding windows. This segment can be used for decoding at next segment. Pros: 50% throughput gain, for twice sliding window size that of sliding window. Cons: difficult to find best aggregation of sliding window size and segment size.

XCOR: proposed by Koutsonikulas *et al.* [35], this protocol using source driven coding decision by using overhearing and notification of adjacent node. Instead of MORE [31] and Code OR [32] using coding strategy of receivers driven. For transmitting data packet, selection of CRSs is done by sender node. According to ETX- proximity to destination CRSs are also sorted by source node.

CCACK: Cumulative Coded Acknowledgement proposed by Koutsonikulas *et al.* [36], upstream nodes receive the ACK of NC traffic from nodes with zero overhead. NSB- ACK (Null Space based ACK) is used for NC to minimize the replication of packet. To broadcast the space information candidate relay merge hash vector in packet header. Producing the linearly independent packet or stop forwarding the packet is directly proportional to the relay which gets hash from its adjacent node. Advantage: throughput and fairness enhanced by 45%, 8.8% respectively as compared to MORE [31].

O3: Optimized Overlay-based OR protocol proposed by Han *et al.* [37], interflow NC and OR concepts are differentiated by O3. This protocol works with the issues of NC, joint OR, and selection of optimal number of coded packets transferred by forwarder.

B. GEOGRAPHIC OR

Figure 7 presents the Geographical-based routing protocol. Description of these protocols are:

1) CBF

Contention based forwarding by Fussler *et al.* [25], procedure for chosen relay is based on contention between various receiver. Node which is nearest to receiver among another adjacent node is selected to transfer the packet. Initially RTF (request to forward) packet sends by source node, then each adjacent node contends with other node to forward a CTF (clear to forward) packet. Sender node forward the data packet to selected candidate relay (selected as per distance-based timer). Advantage, topology exchange

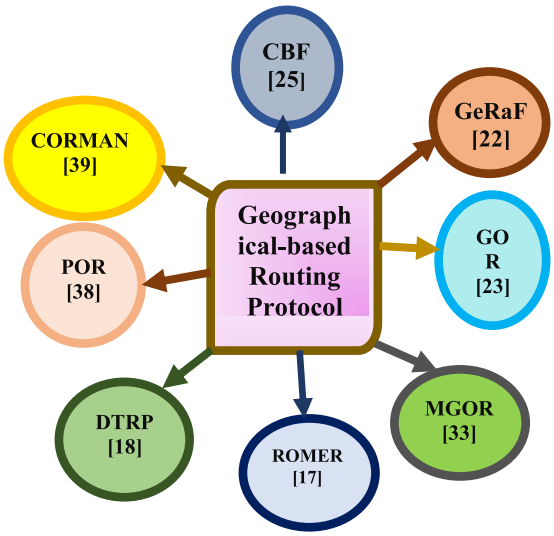

FIGURE 7. Routing protocols in geographical-based OR.

information is not needed while it is required in traditional routing. Disadvantage, delay increases because of sending and receiving RTF and CTF packets. Hike in waiting time due to CTF reply.

2) GeRaF

Geographic Random forwarding proposed by Zorgi *et al.* [22], this protocol evaluate lower and upper bounds of number of hops to reach at receiver node. Analytical characterization of this performance metric with using the hypothesis of Poisson distribution relay is done by GeRaF. Pros: when there are three hops between source and receiver node, this protocol work as idealized scheme. Cons: not work on increased delay and energy parameter which is produced by contention process.

3) GOR

Geographic OR proposed by Zeng *et al.* [23], it eliminates the weakness of CBF [25] by using timer-based approach. Selection of candidate relay is depending upon the EOT metric (expected one hop throughput). This metric considers delay time and distance between node & receiver node that occurred in coordination procedure. Pros: improved throughput gain compared with CBF [25]. Cons: not able to completely keeps away the transfer of duplicate packets.

4) MGOR

Multi-rate GOR proposed by Zeng *et al.* [33], improved version of GOR [23] protocol by using OEOT metric (opportunistic effective one hop throughput). Delay in single hop packet transfer and packet advancement, this metric provides collaboration between them. By using heuristic, metric is expanded by integrating algorithm for candidate selection and local rate adaption. Pros: minimize delay & enhanced throughput as compared to GOR [23].

5) ROMER

Resilient opportunistic Mesh Routing proposed by Yuan *et al.* [17], to make a network more flexible through choosing a candidate relay randomly and transfer of duplicate packet this protocol is used. Basic working principle behind the ROMER is to giving transfer probability to candidate forwarder. Probability one is forwarded with candidate relay, if it received a packet from nearest path. Diversely probability is assigned according to throughput of its downstream outgoing link and number of duplicate packets. 17 hop destination routes, with 92% successful transfer of packet and 5% error rate per hop accomplished by ROMER.

6) DTRP

Directed Transmission Routing Protocol introduced by Nassr *et al.* [18], computation of probability given to candidate relay is different as compared to ROMER [17]. DTRP assigns one probability with each packet transmission if there is shortest distance between sender & receiver node. Otherwise, probability is depending upon number of hops to the receiver node (known as additional routing cost). Pros: 97% packet transmission ratio in medium and large WSN (wireless sensor network). Cons: not address the problem of energy consumption.

7) POR

Position based OR introduced by Yang *et al.* [38], multicast transmission is done by POR to facilitate effective packet transmission in wireless ad-hoc network. Location based information is used in POR for routing in multi-hop wireless Network. Randomness and duplicate packet are generated because of using multicast transmission in POR. Pros: 50% probability of maliciously falling packet transfer and 90% successful transfer of data packet.

8) CORMAN

(Co-operative OR) [39] and COR (Context Aware OR) [40]: CORMAN is proposed by Wang *et al.* and COR is introduced by Zhao *et al.* both address the issue of cross layer, link quality and physical layer wireless propagation. CORMAN and COR are adaptable with high traffic. Path computation of inter node separation is done by RSSI (received signal strength indicator) measures the ACK packets in COREMAN. Another side COR using routing-based decision on various parameters calculated by RSSI like link quality, location of wireless node and movability knowledge (i.e., its speed & direction). COR accomplish 20% to 40% throughput gain and PDR (packet delivery ratio) as compared to GOR [23].

C. PROBABLISTIC OR

Probabilistic-based routing protocols are shown in figure 8. Details of these protocols are:

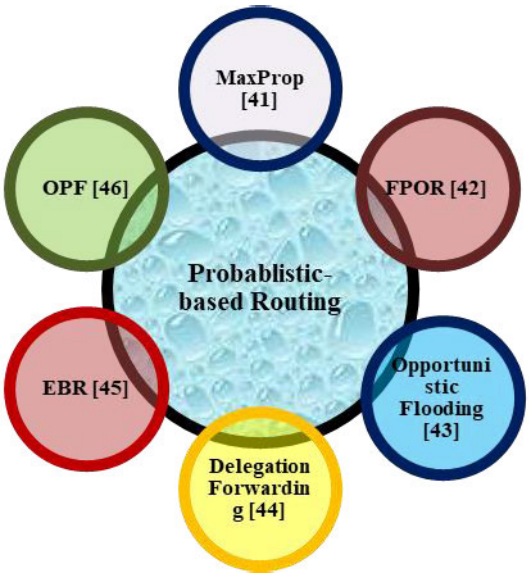

FIGURE 8. Probabilistic-based opportunistic routing.

Max Prop: proposed by Burgers *et al.* [41], first protocol which using probabilistic scheme by merging routing protocol and scheduling.

FPOR: fixed point OR proposed by Conan *et al.* [42], this protocol reduces the packet delivery time by using fixed point of recursive process routing scheme. For calculate the probability of moderate inter-contact duration among the pair of nodes in network, this protocol using various probability distribution methods (like Random, Exponential and Poisson). Pros: in polynomial time it is converge and loop free protocol. Cons: not suitable for real dynamic network.

Opportunistic Flooding: proposed by Guo *et al.* [43], source node takes decision of probabilistic forwarding on the basis of next hop distribution delay. It is cross layer protocol having minimum duty cycle with uncertain wireless link and present working agenda. In opportunistic flooding, network is configured as energy- optimal passing tree. Then under the consideration of MAC, analytical delay characterization is done on tree structure. Pros: flooding delay is minimized and only 20% to 60% transmission energy exhausted.

Delegation Forwarding: introduced by Erramilli *et al.* [44], ordinary probabilistic routing approach that also considers mobility of nodes. At the encounter time, optimal stopping is used to search out whether an encountered node is best relay. In N-node network, forwarding cost in terms of duplicate messages production is O ($\sqrt{}$N). While it is O (N) in greedy relay selection-based forwarding. It is applicable in disaster recovery. But required high bandwidth & storage resources.

EBR: Encounter Based Routing proposed by Nelson *et al.* [45], using quota-based protocol in which during message transfer upper limit of number of duplicate packets are permits in network is fixed. On the basis of previous data, encounter value for every node is predicted in EBR which is same as used in Delegation Forwarding [44]. Successful packet delivery to destination node is depends upon node's a greater number of encounters. Exponentially weight moving average scheme is used for evaluation of encounter value (rate of encounter) for every node. Decay in generation of duplicate packets in EBR as compared to delegation forwarding [44].

OPF: Optimal Probabilistic Forwarding proposed by Lu *et al.* [46]. If overall delivery probability is improved, OPF permits sender node to replicate a particular packet and can choose more than one candidate relay to transmit it. Focus of OPF is to enhanced packet transmission rate. For this OPF metric is calculates by configuring transmission process as an optimal stopping rule problem. Metric shows direct and indirect delivery probability (direct for given packet and indirect for packet transfer to adjacent nodes). To limit the path distance, OPF metric added the threshold value of forwarding (i.e., function of unexpanded hop-count and residual TTL).20% improved throughput gain as compared to delegation forwarding [44].

D. CROSS LAYER OR

It includes three subsections (1) PHY-Aware OR (2) MAC-Aware OR and (3) PHY and MAC OR as presents in figure 9.

(1) PHY-Aware OR, physical interference and/or CSI (channel state information) dynamic concepts are used to enhanced the network throughput. PHY-Aware OR includes the following protocols;

ILOR: interference limited opportunistic relaying with reactive sensing proposed by Blestsas *et al.* [47], inter-relay communication is not needed instead, ILOR uses a dissemination PHY-Aware reactive relay selection approach. After overhearing a pilot signal from the receiver node, every candidate relay measures their RSSI. Optimized candidate relay is elected according to the evaluation of link quality with receiver node. There are two steps to execute relaying approach data packet is transmitted by sender node in first step. At second step, this data packet passes to the receiver node by selected best relay. Pros: short to no delay in relay packet mechanism. Cons: can work up to two hops only.

SPOR: Simple and Practical OR proposed by Lee *et al.* [48]. This protocol can be used for multi-hop wireless network, where node transmits data packet iteratively and recognize its encounter at each hop. At last, ACK is disseminated when receiver node receives a packet. Up to four hops, SPOR accomplishes enhanced throughput as compare to traditional routing. But this throughput becomes marginal when number of hops exceeds to four. Cons: work on linear one-dimensional network model, not adaptable with 2-D, 3-D and wireless networks.

EEOR: Energy Efficient OR proposed by Mao *et al.* [49]. To provide low energy utilization EEOR optimize the prioritization and selection of candidate relay. Transmission power is increases continuously up to highest threshold value by a source node, finds ascending order of CRSs w.r.to distinct transmission power. Source node elected the CRS, which having low expected energy consumption and

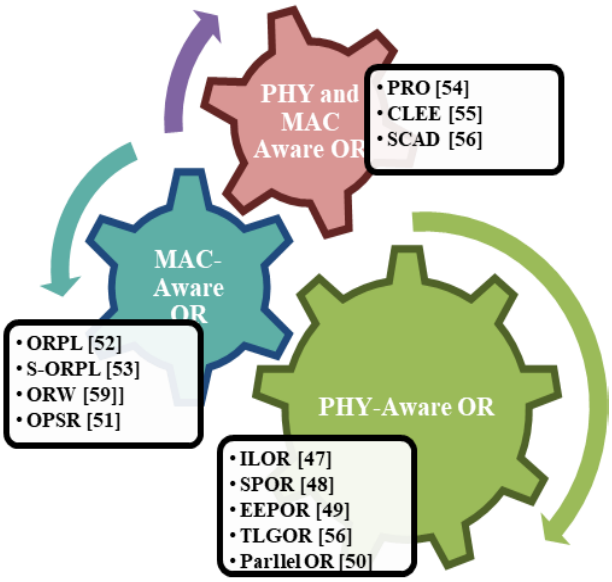

FIGURE 9. Cross layer-based opportunistic routing.

energetic cost. Cons: interference parameter is not addressed that effects energy consumption.

TLG-OR: Topology and Link quality aware Geographic OR proposed by Zhao *et al.* [56]. Selection of CRS is based on geographic location information of node. Sorting of CR is depending upon metric, which contain the link quality, energy measure and weighted sum of progress. By using the metric top priority with minimum transmission delay, candidate relay is selected. Pros: suitable for multi-hop wireless network. Improved QoS (quality of service) and QoE (quality of experience) for video traffic. 40% PDR (packet delivery ratio), 30% SSIM (QoE's structure similarity metric) is enhance as compared to traditional cross layer routing protocol. Cons: interference level increases when work in huge wireless network.

Parallel OR: proposed by shin *et al.* [50], network is divided into controllable size cells to restraint the inter-node interference. TDMA approach is used to forward the packet in these cells. After the organization of network structure, on the basis of SINR (signal to interference plus noise ratio) and cell which it resides, candidate relay is chosen. Data packet is decrypted successfully only when SINR value is greater than predetermined threshold value. In parallel OR, scaling parameter is differentiated in presence of fading for huge ad-hoc network. It provides speculative study of power-delay throughput trade off as number of sender-receiver pair accretes. Pros: it supports various simultaneous flows in huge wireless network. Enhanced total network throughput, power delay and logarithmic boost in the scaling law as compared to non-opportunistic routing protocol. Cons: not address the effect of signaling overhead.

(2) MAC-Aware OR: In this existence and performance are totally rely upon underlying MAC (medium access control). These protocols are energy constraint and work for WSN (wireless sensor network). Sensor node wake-up order is must be considered to avoid retransmission of packet. It includes the following routing protocols:

OSPR: proposed by Bruno *et al.* [51], to enhance multiple concurrent flows in wireless mesh network (WMN), OPSR integrates packet scheduling with OR. For each packet, opportunistic packet throughput gain metric is used by this protocol. This metric calculates the gain of opportunistic forwarder to forward a packet. Opportunistic forwarder node elected as candidate relay, if forwarder node gain is more than γ-times by one of the previously acquired node gain. Packet is buffered in priority queue, after node is selected as candidate relay for accepted packet. Routing efficiency is totally depending on γ factor.

ORPL: proposed by Pavkovic *et al.* [52], IEEE 802.15.4 standard cluster tree architecture is used for routing in ORPL that increases energy efficiency in WSN. At MAC layer because the formation of super frame is adequate, every node can link with multiple parent node in cluster tree. On the basis of ETX value that approaches to destination node, candidate relay is selected opportunistically among various parent nodes. Pros: Enhanced load balancing and data assembling features. It improves network existence and node fairness as compared to traditional routing protocol.

S-ORPL: Scalable ORPL proposed by Duquennoy *et al.* [53], on the basis of specific knowledge of adjacent sub-tree, sender node transmit packet to any terminal node. This protocol considers WSN schedule and propose EDC metric (expected duty cycle). Number of MAC wake-up cycles needed to reach the destination node is presented by EDC metric. Pros: after trivialize this metric; low energy consumption of network and latency improves network life time. Cons: no optimization of CRS.

ORW: proposed by Ghadimi *et al.* [59], this routing protocol used in WSN that uses EDC metric. Low power observes and asynchronous duty cycle used by sensor node while using ORW protocol in WSN. Distributed algorithm is formulating to search EDC optimal candidate relay set in ORW. Pros: in dense network, energy efficiency is twice up to 90%. Average delay is minimized as compared to energy-aware traditional routing protocol.

(3) PHY and MAC Aware OR: some examples are describing as:

PRO: Opportunistic-relaying-based link layer retransmission protocol proposed by Lu *et al.* [54]. For successful retransmission of packets, this protocol uses PHY, MAC and network layer information. Adjacent nodes are allowed to act as a candidate relay for retransmit a packet on favor of sender node. For packet retransmission run time evaluation process is used to predict the transitory link quality to the end node. After this weak relay are eliminated by using local qualification process. At last, from among eligible candidate relay, relay with maximum RSSI value to the end node is elected. Pros: adaptable with 802.11 standards and WMN.

CLEE: cross layer aided energy efficient OR in WSN proposed by Zuo *et al.* [55], to perform energy efficient

routing it uses the information number of candidate relay from network layer, FER (frame error rate) from physical layer and maximum number of packet retransmission from MAC layer. For selection of candidate relay, Dijkstra algorithm and energy drain metric is used. On the basis of Rayleigh fading, hypothesis evaluation is done for end-to-end throughput and delay. Pros: maximized throughput with reduced energy utilization as compared to EEOR [57] and energy aware traditional routing. Cons: only suitable for fixed small wireless network.

SCAD: Sensor context aware adaptive duty cycled OR proposed by Zhao *et al.* [56], to elect the candidate relay SCAD takes account the various cross layer content information like energy consumption rate, link quality, remaining energy and distance. Selected relay is forwarded to the receiver node of the data packet. Selection process of relay is depending on DFD (dynamic forward delay) timer merged within receiver node. Dynamic duty-cycling approach is executed by SCAD protocol, to harmony in sensor node hibernation period by conferring to practical time traffic load and energy consumption rates. Pros: suitable for fixed & dynamic wireless network. While designing an OR in cross layer PHY and MAC, some issues like antennas spatial diversity and various MAC approach with diversified relay is not addressed.

E. OPTIMIZED BASED OR

It includes three categories: Graph based, Utility based, Learning based as depicts in figure 10.

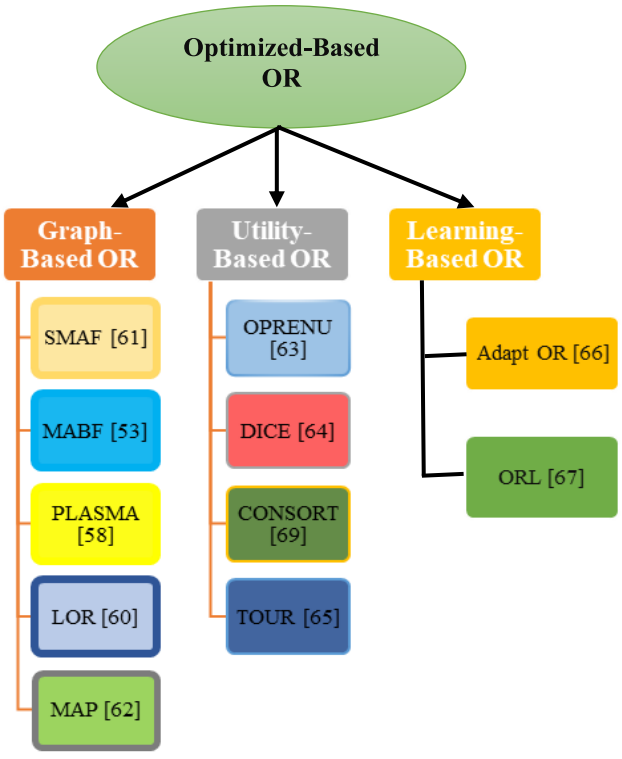

FIGURE 10. Optimized-based opportunistic routing.

(1) Graph based OR: game theory, machine learning, graph theory, and optimization programs are the concepts that used to optimize the OR [32]. Dijkstra and Bellman ford shortest path algorithm is used in Graph based OR. Some graph based OR protocols are as given below;

SMAF and MABF: [61] Shortest Multi-rate Any Path First (SMAF) and [58] Multi-rate Any Path Bellman Ford (MABF) proposed by Laufer *et al.* Abstraction of Dijkstra and Bellman Ford unique path routing algorithm to any path routing is done by SMAF and MABF. The involution of SMAF and MABF algorithm is O (NlogN+ ER), and O (NElogN+ NER) respectively; (where N: is the total number of nodes, E: number of edges and R: number of available bit rate). Same time involution is reinforcing by network when using Dijkstra and Bellman Ford algorithm. Instead of using simple graph, hyper-graph is used to make routing to any path. Hyper-graph is composed of directed hyper-edges and mobile nodes. Weight is given to every hyper-edge connection to a particular node that shows transfer ratio of that hyper-link. Pros: optimal relay selection. Reduction in EATT (expected anytime transmission time parameter).

PLASMA: Multi-rate OR protocol proposed by Laufer *et al.* [58], polynomial-time dispersed algorithm PBF (PLASMA-Bellman-Ford) is used to estimate transfer rate, candidate relay sets and gateway subgroup that reduces the routing cost. Instead of gateway, various possible gateways are merging with mesh nodes in WMNs (wireless mesh networks) that establishes successful delivery of packets. Pros: 98% throughput gain & 2.2 times reduction in delay as compared to MABF [58]. Cons: not suitable for some network resources like hotspot (provide low-utilization and not fair in WMN).

LOR: Localized OR proposed by li *et al.* [60], wireless network is divided by small sub networks which called as CNS (close nodes sets) by using graph theoretical approach in LOR. Local information is used to construct the hierarchal CNSs. On the basis of sender & receiver node localize within same CNS or not, intra or inter CNS OR (same as Bellman Ford distributed algorithm is performed). Pros: adaptable with huge wireless network. Reduced time complexity O(n^2) as compared with MABF [58]; where n is number of nodes in CNS. Attains optimized trade-off between CRSs and scalable routing.

MAP: Multi-constraint Any-path routing algorithm proposed by Fang *et al.* [62], MAP is the enhanced model of SMAF [61]. In which K weight w.r.to K different parameter is given to every K-constraints parameter like time, energy, throughput etc. When K>1, MAP routing protocol is used and it work as a same as Dijkstra algorithm. Auxiliary link weight that shows greatest value for whole weight link is assigned to a link in a network. Then sender to receiver path is evaluated by updated SMAF [61]. CRS includes a node from network if its hyperlink auxiliary weight is reduced.

(2) Utility based OR: It includes following routing protocol;

OPRENU: Opportunistic routing Residual Expected network Utility, proposed by Wu *et al.* [63], this protocol uses RENU value that represents successful transmission of data packet w.r.to its transfer cost. Therefore, reliability cost of wireless network is increases. To consider various forwarders (candidate relay) per hop, RENU utility metric is re-evaluated. For election & prioritization of candidate relay scattered heuristic method is used in OPRENU. Sub-optimal routing decision in OPRENU.

DICE: for optimization of routing selection this algorithm is proposed by Zhang *et al.* [64]. Game theoretical approach is used in DICE where sender node may be selfish player or cooperative player. According to formation of the monotonous rule players are sorted to perform local optimization (routing and allotment of resources) by players. Dissemination and encoding cost allotted to the sender and forwarded relays in place to improve its own or social payoff is shown by player's rule. Pros: use of decentralized bargaining algorithm attains social optimization in cooperative player's scenario. By using pricing approach for player's, it accomplishes Nash equilibrium, in selfish player's scenario. 47% improved throughput as compared to PDR and MORE.

Consort: node constraint OR in WMN (wireless mesh network) proposed by Fang *et al.* [69], it is dispersive iterative algorithm which is used the gradient approach. Issue of existence of various simultaneous source nodes in WMN is resolved by consort program. Goal of this program to get optimized complete utility or gain of various simultaneous sender nodes with respect to node constraint. On the basis of relay and sender node, activity observed from last iteration. Consort modifies the Lagrange multiplier into dispersive way. After this every relay and sender node regulate their own activity according to modified Lagrange multiplier.

TOUR: Time-sensitive Opportunistic Utility-based Routing protocol proposed by Xiao *et al.* [65], it provides successful transmission of data packet with minimum delay but higher path cost. Initial benefit value is allotted to data packet and it decreases with time. Benefit value increases with respect to importance of packet. This protocol retains utility function for each packet (utility function = benefit value - delivery cost of packet). It considers the issues of time varying benefit value and encounter of probabilistic node. These issues are resolved by the concept of time varying optimal candidate relay set. Pros: goal is to higher the remained time value of packet, when packet arrives at receiver node. Optimal expected utilities.

(3) Learning based OR: it includes the following routing protocol:

Adapt OR: Adaptive Opportunistic routing proposed by Bhorkar *et al.* [66], without using the link quality and network topology information, Adapt OR reduces the average per data packet routing cost. Working of adapt OR includes (a) source node forward the data packet (b) after receiving a packet by nodes in candidate relay sets it sends the ACK. ACK keeps the EBS value (estimated best score value). (c) On the basis of random pattern source node chooses the routing action (end of forwarding a data packet or selection of candidate relay). (d) After the reception of EBS value from adjacent nodes, source node updates their score vector and their own EBS value. Reliability of this protocol is totally depending on the successful transmission of control packet that contain the EBS related information. Performance is decaying w.r.to loss of control packet in lousy wireless propagation scenario. Long-run average cost per packet for routing is reduced.

ORL: Opportunistic Routing with Learning proposed by Tehrani *et al.* [67], to calculate the convergence rate of average network performance "regret performance metric" is established. Predicted additional cost expanded over a horizon of T data packet is estimated by regret metric. The election of the candidate relay node is on the basis of its probabilistic link and it uses dispersed online algorithm. To optimize regret scaling with network size ORL protocol provides local learning for each node. According to a number of wireless links, polynomial regret order is attained by this protocol. Instead of using a probing packet to learn the wireless link, piggybacking data packet is used. This protocol not addresses the issue of MAC layer.

F. SECURITY BASED OR

Security based approach are proposed to achieve secure and reliable path from source node to destination node. Many security-based routing were proposed in wireless network, the description of few of these protocols are as described below and presented in figure 11.

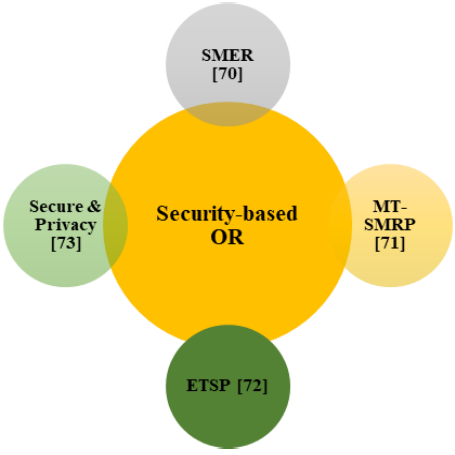

FIGURE 11. Security-based opportunistic routing.

SMER: In 2019, Secure Multi-Tier Energy Efficient Routing (SMER), Security-based routing is introduced by Dhand *et al.* [70]. This protocol works in 2-phases. In first phase: K-means with ant lion optimization to minimize the power consumption. In second phase: to decrease the packet loss & improve security in network; Elliptic Curve Cryptography (ECC) is used. It provides high throughput, reduced energy utilization, low end-end delay, and security as compared to LEACH-C.

MT-SMRP: Message Trust-based Secure Multipath Routing Protocol (MT-SMRP), Security-based routing is introduced by Dhurandher *et al.* [71] in 2020. For message encryption; trust, soft-encryption algorithm, and disjoint path are used. Acknowledgment scheme is implemented for trust model. It provides security with reliable average latency and packet delivery.

ETSP: Enhanced Trust-based Security Protocol (ETSP), Security-based routing is introduced by Sharma *et al.* [72] in 2020. This protocol is designed to manage blackhole attack in OppNet. Prophet context-based routing protocol is used to identify blackhole attack. ONE tool is used to simulate this protocol.

Security & Privacy-preserving: This protocol is introduced by Rashidibajgan *et al.* [73] in 2021. The objective of this protocol to prevention from Sybil, dropping, and selfish attack. It provides integrity, confidentiality, privacy, and anonymity in network. Game theory-based cooperation scheme with sharing public-key is used to encrypt the messages in network. To enhance network performance linear discriminate function is used. It provides improved performance as compared to epidemic, and prophet protocol.

G. CONTEXT BASED OR

Probability based approach attains lower delivery ratio of data packet. To eliminate this drawback context-based approach is introduced presents in figure 12. It includes following scheme:

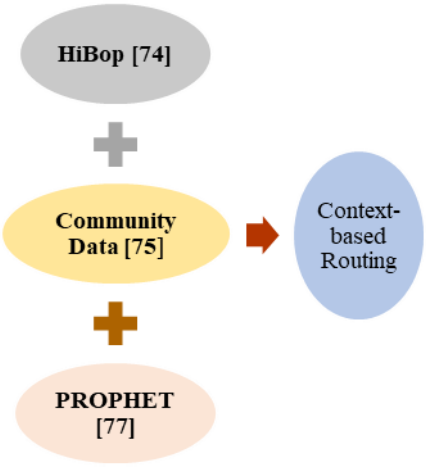

FIGURE 12. Context-based opportunistic routing.

HiBop: In 2007, History Based routing is introduced by Boldrini *et al.* [74]. Every node carries the context ''information'' and during this IT (identity table) is generated. Nodes can be recognized in network by using IT table. To save nodes attribute History Table is updated accordingly. History table keeps the information of destination and encountered node. HiBop algorithm has three steps:

''Emission phase'': production of data packet; transmit this packet to their adjacent node as well as packet replication to receiver node is done by sender node during working in this phase.

''Forwarding phase'': Election of optimized candidate relay; first context information & nodes' mobility information is broadcast and then IT table and history table is used. Candidate relay transmit the data packet (with no duplicate data packet) to its receiver node.

''Delivery Phase'': Last phase; when receiver node receives the packet by candidate relay. Pros: Minimized buffer usage and network traffic. Increases in reliability as compared to Epidemic and Prophet routing protocol.

Community Data: In 2009, community data-based context routing protocol for opportunistic routing is proposed by Niu *et al.* [75]. To increase data packet delivery ratio; replication base packet transmission approach produces a greater number of data packet. Due to this traffic increases and performance lack in network. To eliminate these drawbacks community-based transmission scheme is proposed. In this approach; relation vector that carries the information of encounter time is maintained by every node. Between two nodes; relationship strength is identified by vector. In this approach network is divided into distinct communities by using Newman's weighted network algorithm and relation vector.

Inter network and intra network are ways to work in Newman's weighted network algorithm. Whenever source node and destination node exist in same community and packets are transferred to receiver node through active relay; intra community data packet transmission will work. In inter community, source node generates the data packet and fixed number of copies to be created. With using active relay node; destination community is searched. Whenever destination community receives data packet, rest data packet copies are eliminated. Pros: TTL (time to live) increases with improvement in data transmission ratio. Reduced in resource utilization and performance improved as compared to spray & focus [76]. For acknowledgement process, Epidemic algorithm is used. Cons: only applicable to community Opportunistic network.

PROPHET: In 2003, probability routing protocol using history of encounters and transitivity proposed by Lindgren *et al.* [77]. On the basis of recognized contact history, this approach evaluates the transfer predictability from source node to receiver node. Node will pass the packet to its adjacent node only if node has significant transfer predictability value. Probability metric known as ''delivery predictability'' is used in [77]. Probability of successful transfer of packet to receiver node from local node is by this metric. The nodes' delivery predictability value increases, whenever nodes are mostly encountered and vice-versa. Delivery overhead is minimized in prophet as compared to epidemic routing.

H. SOCIAL-AWARE BASED OR

For election of appropriate relay node selection many protocols used social aware based information. The selected

social aware protocol is shown in figure 13. Description of these protocols are:

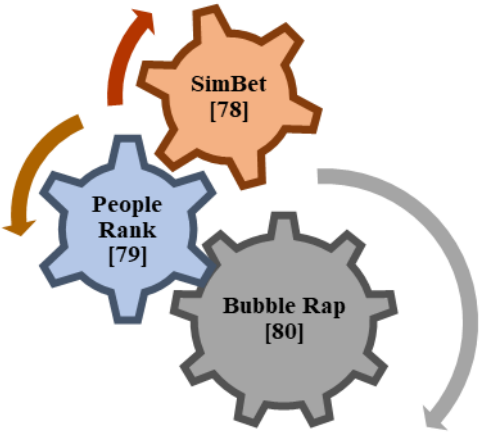

FIGURE 13. Social-based opportunistic routing.

1) SimBet

In 2007, social aware based routing protocol is proposed by Daly *et al.* [78]. It works in two phases; in first, centrality metric is used to interchange the data packet among community and in second phase, similarity matric is used in the community to send the data packet to receiver node. Freeman's degree, closeness, and betweenness functions of centrality is used to calculate the centrality and similarity matric of the node. This protocol provides lower delivery delay & overhead.

2) PEOPLE RANK

In 2010, social opportunistic routing protocol is proposed by Mtibaa *et al.* [79]. It used the concept of web page indexing of Google. According to the importance of the node, rank is given to each node in the network. Whenever two nodes contacted to each other, they share their people rank. People rank matric is calculated by degree and centrality of the node. Attains enhanced delivery data rate by 50% as compared to epidemic protocol.

3) BUBBLE RAP

In 2008, social aware based routing protocol is proposed by Hui *et al.* [80]. Local & global rank is given to every node in the network and each node is related to at least one community. protocol uses betweenness centrality metric to rank the node. Whenever node sends the data packet, it Bubbles/transmit it to higher rank node in the network. This protocol is not applicable to dynamic/random network.

I. ENERGY BASED OR

Utilization of energy is important concern during designing the protocol. Many energy-based protocol were introduced in wireless network. Figure 14 shows some energy-based routing protocol and their description are as follows:

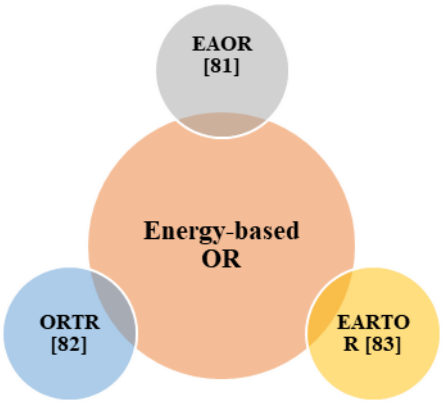

FIGURE 14. Energy-based opportunistic routing.

1) EAOR

Energy Aware Opportunistic Routing (EAOR) protocol is proposed by Spachos *et al.* [81] in 2012. Coordination between Quality of Services and energy efficiency is done by this protocol. It increases network lifetime by 25% as compared to simple OR with minimize the packet delay. It reduces the energy consumption by 35% as compared to traditional routing. It uses Request To Send (RTS), Clear To Send (CTS), ACK, and DATA, four types of packet during routing. Relay node is selected according to their minimum distance to destination node. OMNet++ is used to simulate this model.

2) ORTR

In 2009, Opportunistic Real Time Routing (ORTR) protocol is proposed by Kim *et al.* [82]. According to delay factor, transmission power is adjusted with efficient delivery of packets. It provides real-time data delivery with minimize energy consumption. Heuristic approach which combined MAC-layer and routing-layer features to complete real-time requirements in network. NS-2 simulator is used to simulate ORTR and compared with other protocols. It is ill-suited periodic real-time data because of low bandwidth in application layer.

3) EARTOR

In 2010, Energy Aware Real Time Opportunistic Routing (EARTOR) protocol is proposed by Yang *et al.* [83]. QoS is maintained with the balanced in between end-to-end latency and energy consumption. On the factor residual energy, bidding approach is used to select the relay node. It provides enhanced data delivery ratio with reduced energy consumption in real-time environment. MATLAB is used to implement EARTOR and compared with other protocols.

J. FLOODING BASED OR

Many copies of data packet are produced by sender node and transmit into network. Duplicate data packets are produced until receiver node not received the data packet. It having

two categories: - (1) Uncontrolled (2) Controlled as shown in figure 15.

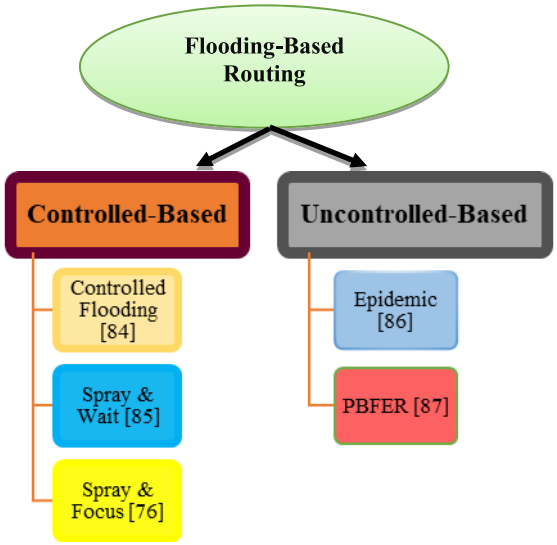

FIGURE 15. Flooding-based opportunistic routing.

1) CONTROLLED-BASED FLOODING

Replication of data packet by nodes is controlled by this approach. It includes the following protocol:

Controlled Flooding: in 2005, controlled flooding is proposed by Khaled *et al.* [84]. Time to live (TTL), kill time, and willingness probability are three main elements, through which flooding is controlled. Every node in network is self-governing, each node kept the information about their self and about data packet. Probability function is used to find the willingness level for each forwarder node. Now to transmit a data packet from sender to receiver node, sender node gives signal for transferring a data packet. Forwarder node ACK the signal and accept the data packet, when its willingness level is not zero.

Spray & Wait: In 2005, spray and wait routing protocol is proposed by Spyropoulos *et al.* [85]. It has two phases to control the flood level in network. Either source node or relay node with L distance, broadcast the L (limit) number of data packet in network, this work is done in spray phase. In wait phase, every relay node keeps a copy of data packet and forwards this packet to receiver node only when receiver node doesn't receive the data packet during spray phase. Pros: minimum delivery delay & number of transmissions as compared to epidemic routing protocol [86].

Spray and Focus: In 2005, spray and focus routing protocol is proposed by Spyropoulos *et al.* [76]. In Spray phase, L "forwarding tokens" are generates whenever a new data packet is produced by sender node. Supplementary copy of particular data packet can be produced and transferred by a node, who keeps the forwarded token. Focus phase will work, only when relay node has a particular data packet with only one forwarding token. According to transferring criteria data packet is transferred to distinct relay.

2) UNCONTROLLED FLOODING-BASED

It includes following approach.

Epidemic routing protocol: in 2003, epidemic approach is introduced by Vahdat *et al.* [86]. This routing protocol doesn't have any constraint on production of duplicate data packet by sender node. It has no transmission delay. In network, data packets are exchanges randomly between nodes and ensures that all data packet received by every node. Replicated database is harmonized by this protocol. Pros: ensured delivery of data packet. Cons: Needs considerable higher bandwidth and buffer usage.

PBFER: in 2005, Priority based forwarding in Epidemic Routing approach is proposed by Sharma *et al.* [87]. FIFO (first in first out) approach is used by epidemic routing protocol. Unlikely PBFER using priority method with FIFO, in which before sending the lower priority message, higher priority message is flooded in network. Security and urgency of data packets are two parameters through which priority is decided. As urgency of data packet increases its correspondingly priority is also increasing. But for security of data packet, it works in reverse order, for higher security data packet, lower priority is assigned to packet and vice versa. Advantages: minimize overhead ratio and latency w.r.to number of nodes [87].

K. MISCELLANEOUS OR

This section includes miscellaneous opportunistic routing protocols. It includes machine learning based, and utility-based routing. The description of these protocols are as follows:

HiLseR: in 2021, learning-based routing approach is proposed by Banyal *et al.* [69]. It provides efficient routing in Opportunistic network with internet of things (OppIoT). Controlled parameterized flooding with opportunistic sector-based decentralized transmission approach is used to achieves high packet delivery probability with reduced energy consumption. Ordinary node and apex node are two categories of nodes are used in OppIoT. HiLseR is the partially context-information based protocol.

RAPID: in 2007, utility-function based RAPID protocol is proposed by Balasubramanian *et al.* [88]. Average delay matric is maintained by using packet utility-value. Initialization, direct delivery, packet replication on the basis of marginal utility-value, and termination are four main phases of RAPID protocol. Custom event-driven simulator is used to simulate RAPID. It reduces maximum delay by 30%, 35%, 45% as compared to MaxProp, Spray &Wait, and Random protocol respectively.

PREP: in 2007, PRioritized Epidemic Protocol (PREP) Routing approach is proposed by Ramanathan *et al.* [89]. It uses prioritized approach to broadcast the packet in the network. PREP is enhanced version of Epidemic protocol and eliminates its drawback. Epidemic protocol can't work efficiently, when network load increases. Therefore, it produces high no. of messages dropped. Priority of each

message is calculated by their TTL & present overhead cost to destination. High priority is given to that message, which is closed to destination and thus transmitted. It uses limited buffer storage capacity with limited bandwidth.

ORFP: in 2021, Optimized Random Forest Protocol (ORFP) approach is proposed by Dalal *et al.* [90]. This protocol used the feature of random forest machine learning algorithm and firefly optimization algorithm. Initially, set of relay node is extracted by using random forest, then firefly algorithm is used to select only one relay node from the set. It achieves improved data delivery ratio, reduced overhead ratio, and minimize average hop-count as compared to traditional routing. This protocol is simulated on ONE tool. ORFP can't able to identify malicious node in the network.

RQ:3 What are the imperative network parameters/factors to evaluate the performance of secure and reliable routing?

Ans: Diverse factors were existing to evaluate the performance of protocol in opportunistic network. Name of the factor, description, units, and their requirement are discussed in table 7.

TABLE 7. Network parameters.

S. No	Name of Parameter	Description	Units	Required for Efficient Protocol
1	Throughput	The amount in which packets are go through in the network.	Kilobits Per Seconds (Kbps)	High
2	Energy Consumption	Consumption of energy by the node during simulation time.	Joules (J)	Low
3	Packet Delivery Ratio	The ratio of acknowledged packets at receiver node to the number of generated packets at the source node.	Percentage (%)	High
4	Delay	Moderate travel time taken by packet from source node to destination node.	Millisecond (ms.)	Low
5	Overhead Ratio	Number of duplicate packets produced to per original packet.	No. of Nodes	Low

RQ:4 What are the existing companies and applications in the area of OppNet?

Ans: To discover the answer of this question; diverse research paper has been studied in depth.

Four companies were discovered and reviewed in this SLR. Figure 16 illustrates the year, founder, services/products, and features of these organizations [68]. Opportunistic network is felicitous in numerous fields like; smart city/country, monitoring in environment, commercial, proximity-based, censorship circumvention, IoT in industry, and many

TABLE 8. Applications of. OppNet.

S. No.	Name of the Application	Description	Size of Network (Small/ Medium/ Large)
1.	Smart City/ Country	OppNet nodes with gadgets are linked. For example, vehicles, walkers, street light, road light etc., are connected to provide communication.	Medium to large.
2.	Personal/ Proximity-based/ Neighbor-hood Special Concern	Distinct group of persons residing near to each other but not required to linked always; are connected to broadcast their data, problems, conversation, etc.	Small.
3.	Environmental Application	To observe the soil characteristic, animal movement, state of atmosphere and oceanographic, etc. OppNet can work efficiently.	Small to Medium.
4.	Challenged/ Disaster/ Crowded/ Event Area	The vulnerability/ threat message about tidal waves/ earthquake/ volcano can be disseminate into small group of people to large group.	Small to large.
5.	Censorship Circumvention	Either in sparse region or dense region this network gives opportunity of freedom to the user to disseminate their notion. OppNet is work as censorship circumvention technique but ill-suited for government organizations.	Small to large.
6.	Space Agencies	OppNet is also applicable in worldwide space terminal communication for observance of all functions, message transmission in terrestrial planet, space flotsam & jetsam, and etc.	Small to large.
7.	Commercial Application	For various commercial applications like; in data-warehouse (for transaction of goods & money, information exchange), transport system, construction of plant monitoring, and etc.	Small to large.
8.	Public Service & Security	It includes air terminal function control, unnamed flying vehicles' communication, remote information system, security & collapse communication, and etc.	Small to large.
9.	Special Rangers	Ranger includes the particular profession like policemen/ National Disaster Response Force (NDRF)/ firefighters are grouped together to provide communication in OppNet.	Small.
10.	Internet of Things/ Industry	In small region, less group of people having large n umber of gadgets to provide complete control in industry 4.0. High density of devices is required to enable the "Industry IoT".	Small.

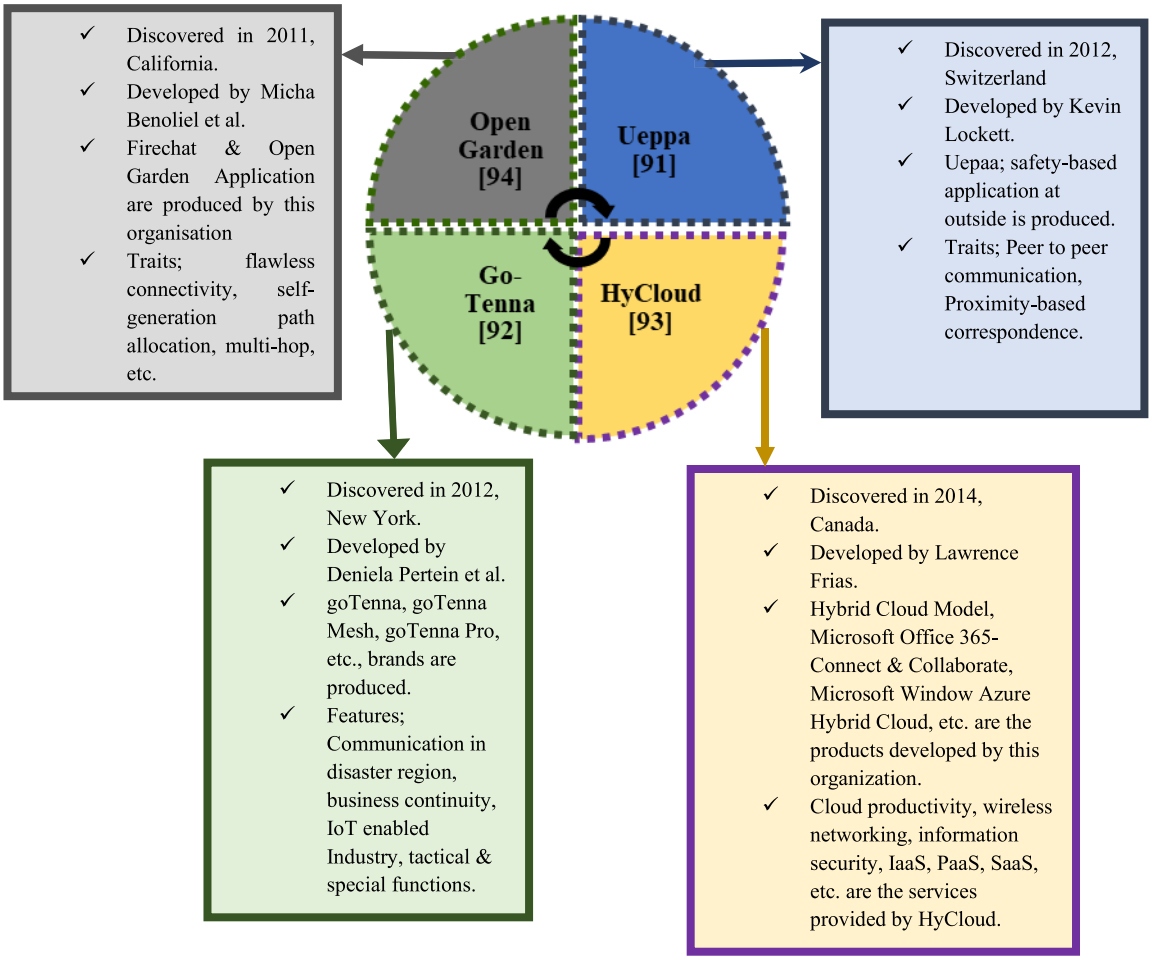

FIGURE 16. Organization related to opportunistic network.

more. Like Instagram, Facebook, WhatsApp or Twitter; there is no such leveraged application is endured but after this some application of OppNet are discussed in Table 8.

RQ:5 What is the importance of this SLR for the researchers in the field of OppNet?

Ans: While addressing the significance of SLR in the field of OppNet; diversified leverages were encountered.

(1) This SLR provides guidance to the researcher/authors to devise the present state of research in the area of routing in OppNet.

(2) Set of research questions and quality estimation criteria gives the sub-region of research topic that should be consider for further research. Author can find new angle and explore the concept in precise direction.

(3) Recognition of specialist in the particular field can be discovered by SLR. Author can focus on those papers who is written by specialist/expert. Expert term can be defined as ''the researchers who written many papers on same domain''.

(4) After studied the SLR on OppNet; author can identify & understand the approach/technique used in previous work to enable the efficient protocol.

RQ:6 What are the dominant issues, challenges, and future terms in OppNet?

Ans: Assorted issues, challenges, and future taxonomy for opportunistic routing in wireless network were addressed in this section. Figure 17 describes the terminology concerned to various issues, challenges, and future terms. The explanation of few issues are; context-alertness: how to discover the desirable relay node in the terms of data/context, management of resources: due to limited resources in network; how to manage these resources effectively to send the message successfully from source to end node, Information Management: due to bounded buffer capacity in OppNet node, how to manage the data is also significant issue in OppNet, message replication, services, data deployment/offloading and etc., issues were encountered.

Distinct challenges were discovered during designing the protocol; Congestion in OppNet: when node altruistically disseminate the packet through replication congestion in OppNet become the major challenge. Order of message dissemination: To sort which data packet should be sent into which priority is also considered while routing in network. Evaluation of elasticity: to estimate the flexibility of

TABLE 9. Comparative studies of selected tools in wireless network.

S.No.	Tools Name	Year	Authors	Open-Source	Language	Features	Miscellaneous information
1	Adyton [95]	2015	Papanikos et al. (University of Loannina Greece).	Yes	C++	Event driven network simulator. Work on LINUX OS. Large no of routing protocol is adaptable with this tool (like direct delivery, spray & wait, PROPHET etc.)	Available at https://github.com/npapanik/Adyton Processing of original traces are necessary to provide adaptability.
2	SUMO [96]	2011	Michael Behriseh et al. (German Aero space center)	No	C++	Simulation of Urban Mobility (SUMO). Applicable to vehicle to vehicle and vehicle to infrastructure. It provides outside interaction simulation with NS-2 & NS-3 by using Tracl.	Available at: https://github.com/eclipse/sumo/ Portable to windows and Linux. For huge environment "origin/ destination metrics" is used. It provides microscopic simulation scenario.
3	Bonn-Motion [97]	2010	Nils Aschenbruck et al. (University of Osnabruck, Germany)	Yes	JAVA	Can work on Unix and Microsoft windows OS. Generates node's movement environment in MANET.	Available at http://bonnmotion.net.cs.uni-bonn.de/ Simulation scenario is easily portable to various tool like ONE, NS-2, NS-
4	ONE [98]	2009	Ari Keranen (Hlsinki University of Technology)	Yes	JAVA	Opportunistic Network Environment (ONE). Work on two Mode: Batch Mode (Multiple Distinct Parameter in huge network), and GUI Mode (used for testing, debugging and simulation).	Available at: https://akeranen.github.io/the-one/ User friendly GUI. User can easily configure the simulation scenario by using setting files.
5	NS-3 [99]	2006	Tom Henderson (National Science Foundation US)	Yes	C++	Network Simulator 3(NS-3). Highly compatible to communicate with real world network scenario due to its interfacing flexibility with LINUX APIs.	Available at: https://www.nsnam.org Network Simulator 3 (NS-3). To provide the transparency in node's movement during & after the running network code Net Anim software is used with this tool.
6	PedSim [100]	2003	---------	Yes	C++	Pedestrian Simulator (PedSim). Provide adaptability of visual studio on window OS. Provide real time visualization of pedestrian with user interfacing.	Available at: http://pedsim.simaril.org/information/ Developed and tested on Linux OS. Automatically or by using text file; manually mobility of pedestrian may be visualized.
7	GloMoSim [101]	2001	Parallel Computing Laboratory (University of California, Los Angeles)	Yes	C	Global Mobile information system Simulator (GloMoSim). Parallel discrete event simulators. Work on Unix & Windows both.	Available at: http://pcl.cs.ucla.edu/projects/glomosim/ Random way points and Random drunken are two model for node's mobility. It gives accurate result, in heterogeneous set of parallel computers in huge network.
8	QualNet [102]	2001	Rajive Bagrodia (University of California,	No	C++	Quality Network (QualNet). Can used for huge network.	Available at: http://www.scalable-networks.com/products/qualnet/

TABLE 9. *(Continued.)* **Comparative studies of selected tools in wireless network.**

			Los Angeles)			Simulation can be done on multiprocessor and multicore system in huge & high-fidelity scenario.	Applicable to non-homogenous network, distributed applications. Difficult to install on Linux platform.
9	OpNet [103]	Invented in 1986, but publicly available in 2000.	Alain Cohen's	Yes	C++	Optimized Network engineering tool (OpNet) Five phases are included in modeling &simulation cycle of OpNet.	Available at: http://www.opnet.com/ For reusability; network node, process and parameter editor are used in hierarchal model.
10	NS-2 [104]	1989	Floyd and Mc Canne	Yes	C++	Tool can work on wired network: LANs, point to point etc. It can work on wireless network: satellite communication, propagation model etc. Highly supported platform and protocol.	Available at: http://www.isi.edu/nsnam/ns/ Applicable in education & research, real audio, FTP, TELNET, constant bit rate traffic model etc.
11	NetSim [105]	1992	Tetcos is a private company in Bangalore, India.	No	JAVA	Network Simulator (NetSim). Provide communication environments with WWW site. Network model implementation authority is given to user.	Available at: http://tetcos.com/software.html Data communication and audio environment for HFGCS is evaluated and implemented by NetSim OO.
12	OMNET ++ [106]	1992	Andras Varga	Yes	C++	Object Modular Network Test bed in C++ (OMNET++). Highly cohesive and excluding node's activity from node parameter. All information for this tool is easily available in tutorials and in user guides.	Available at: https://omnetpp.org OMNET++ can't work directly in oppnet; INET framework is used to simulate the opportunistic network. It provides 2-D and 3-D support for visualization of result.
13	Legion [107]	----------	Bently System	No	GUI-based	Can work on three human mobility model; Strategic, tactical and operational. After some modification in legion studio outcome; it can be used as input parameter in opportunistic network.	Available at: http://www.leg.com/ Applicable to bridge analysis. Can work in structural analysis & detailing. Some parameter of pedestrian can be modified like; destination moving speed, arrival distribution, mobility objective etc.

protocol like security of protocol, delay, dropping of message, replication of message, and etc., is important challenge. Energy & Mobility level, data rate & bandwidth, lack of resources are also leading challenges in OppNet. Future terms are described in this subsection. Smart gadgets and wearable devices integrated with sensors (GPS, camera, microphone, and etc.,) when accessible in the atmosphere to collect the data automatically is known as mobile sensing with OppNet. In mobile computing with OppNet, mobile remotely [68]. Other future application is how the OppNet can be used in budget with scalability. node opportunistically shares their data in terms of context with additional information like; software & hardware resources, and able to execute their task.

RQ:7 What are the available tools for simulating the wireless network?

Ans: There are numerous tools are existing to implement wireless network. From table 5, authors used diverse tools like NS-2, NS-3, QualNet, OMNET++, GloMoSim,

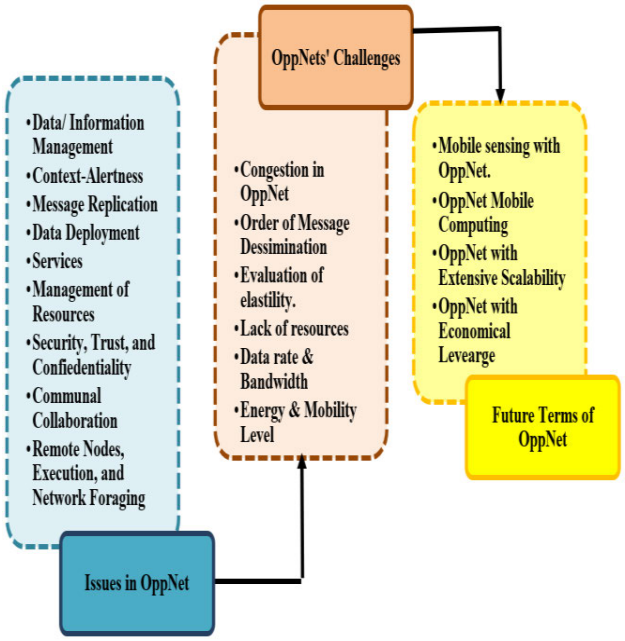

FIGURE 17. Issues, Challenges & future terminology of opportunistic network.

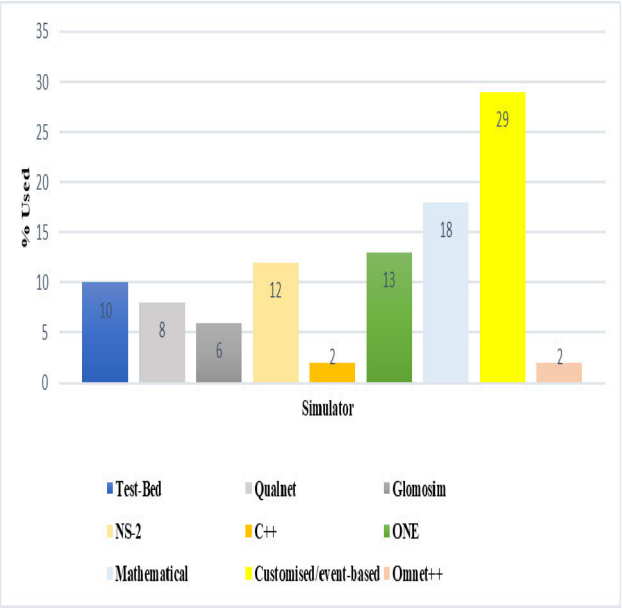

FIGURE 18. Use of different simulator (%) in opportunistic routing.

Adyton, MATLAB, SUMO, Bonn-Motion, ONE, PedSim, OpNet, NetSim, Legion, Drift emulator, Monte-Carlo, and TOSSIM. Table 9 describes the comparative study for selected tools, which are used to implement wireless network.

VI. DISCUSSIONS

In this section, important outcome from this SLR is discussed, which will be helpful and effective for researchers in their future work. After addressing RQ-1; it was found that how MANET & OppNet routing is different and their main difference is bundle layer, which used store-carry-forward approach. Researcher should keep this knowledge while design new protocols in OR.

Link state, geographical, probabilistic, cross-layer, and optimized categories are defined in OR. 65 research papers were included and compared with their introduced year, focus region, methodology used, future area, implementation type, citation-score, and quality score were described in table 5. From RQ-2 it was analyzed that different tools are exists for implementation. Detail of percentage used of different simulation tool are shown in figure 18.

Researcher can select the tool according to their concept, either they can mathematically prove their idea or use the tool. Many authors were also used both type of implementation (M&T). From 2003-2008; test-bed and even-based simulator were used mostly, but in today's era most of the simulation are done on ONE tool. Important parameters which effect the performance of routing were discussed during address the RQ-3. Researchers should evaluate their protocol in terms of these factors. Existing applications and companies were explained while answering RQ-4. It may give opportunity to the researcher to create new application in the area of OppNet. Readers were found the importance of SLR after read the answer of RQ-5. After addressing RQ-6; diverse issues, challenges, and future terms were described, through which researcher can focus how to resolve the issue with challenges by their effective protocol. Comparative study for selected simulating tools were addressed in RQ-7. Researchers can select the tool according their proposed work.

VII. CONCLUSION AND FUTURE WORK

Routing protocols applicable to opportunistic network with their performance parameters and other issues are considered in this Systematic Literature Study (SLR). Specified steps related to SLR were followed like formulation of leading RQ, describing exploring method for data resources, inclusion & exclusion benchmark for elimination of research articles, quality estimation criteria, and data extraction criteria from elected articles. Diverse RQ were formulated and illustrated in the SLR. Many digital sources, library, and search engines were explored to find the answers of questions. Searched articles were also eliminated in this study on the basis of their quality evaluation and data included in these papers. Only 65 articles were considered out of 1215 papers identified from digital sources.

This study concludes that various concepts were introduced in the field of routing in OppNet. Resilience of protocols depends on their performance metrics at the time of their simulation on specified tool. Analysis & factful review of selected papers were discussed in section IV. Throughout this, author can easily overview the past technique, problem encountered, future scope, and quality of articles.

Opportunistic mobile sensing and computing were also encountered as future terms on which researcher can emphasize their work. How the user can take the leverage of scalability in more economical way can be focussed in further research. Moreover, security in network, confidentiality in messages (if malicious activity happens), trust in

context-awareness routing, and privacy among nodes are also needs to be focussed.

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