Method for Ad-hoc Blockchain of Wireless Mesh Networking with Agent and Initiate Nodes

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***Abstract*—Method for Ad-Hoc blockchain of wireless mesh networking with agent and initiate nodes is proposed. Minimizing the number of hops and maintaining connectivity of mobile terminals are concerns. Through simulation studies, it is found that increasing number of initiator nodes caused nodes to route a large number of messages. Thus, these nodes will die out quickly, causing the energy required to get the remaining messages to increase and more nodes to die. This will create a cascading effect that will shorten system lifetime. Multi-hop routing, however, imply high packet overhead, (more nodes in the network means more hops will be available). The packet overhead of the multi-hop routing is extremely high compared to single path routing since many nodes near the shortest path participate in packet forwarding. This additional overhead caused by moving node can cause congestion in the network.**

Keywords—Blockchain; Ad-hoc network; agent and initiate nodes; the number of hops: connectivity; routing protocol; multi-hop routing; packet forwarding

I. Introduction

Blockchain was born in 2008 when an individual or group of unknown nationality named Satoshi Nakamoto published a paper on Bitcoin. There are two types of blockchains, Public and Private. Public blockchains allow an unspecified number of participants to participate in block generation, but on the other hand, there is a problem that processing speed and safety are impaired due to this. On the other hand, with private blockchains, the authority to generate blocks is given only to a limited number of participants, making it difficult to differentiate from conventional databases and making it impossible to demonstrate the inherent strengths of blockchains.

In this study, ad-hoc blockchain of wireless mesh networking is proposed for private blockchains for mobility services. Connected cars are called as smartphones with mobility services. Mobile devices, mobility service sharing, sometimes, needs ad-hoc blockchain functions such as payment confirmation, etc. In such cases, ad-hoc wireless mesh networking is needed. One of the problems of the ad-hoc wireless networking is continuous connectivity among the moving targets of mobile objects, cars, mobile devices, etc.

Wireless mesh network technology, which connects access points by wireless communication, is being considered as an access network [1], [2], [3], [4]. A wireless mesh network consists of access points with interconnection functions called mesh STAs. In a wireless mesh network, route control is necessary for multi-hop communication between mesh STAs. Each meshSTA exchanges information used for routing on the network. Since this information exchange is also performed by wireless communication, there is a possibility that the opportunity of data packet delivery may be deprived due to the collision caused by the communication.

On the other hand, in wireless mesh networks, there are studies to improve packet transfer efficiency by adjusting the transfer rate of each path [5], [6]. There is also a method of leaving routes that can achieve high throughput by deleting unnecessary routes from multiple routes [7]. In addition to these, there is a method of constructing detours using signaling messages included in standard specifications [8], and research that utilizes the characteristics of hash functions when searching for moving user terminals in mesh networks [9]. Also, there is a method [10] that exchanges position information with adjacent mesh STAs on the Euclidean plane, constructs a Delaunay overlay network, and builds detour routes with neighboring mesh STAs that are not directly adjacent physically. Furthermore, we proposed a basic method for route design and route control using the estimated adjacency relations between mesh STAs [11], and applied it to IPv6 networks [12]. Moreover, there is Ad-hoc On-Demand Distance Vector (AODV) Routing [13]. There are some related research works to the Ad-Hoc wireless network [14]-[24]. There is such related research work to Ad-Hoc wireless blockchain networking at all.

The method proposed here is based on the ad-hoc networking protocol for a block chain of peer-to-peer (P2P) networks with mobile devices. In particular, nodes of mobile devices move from one coverage area to the other coverage areas. The locations of the mobile devices are known with GPS. Therefore, only thing it has to do is to establish ad-hoc network in the moved network area. An agent node is assumed to be an initiate node for establishment of the network. Thus, a blockchain can be created in Ad Hoc manner. This would be useful for “Web3.0” because "Web 3.0" is a decentralized Internet realized by blockchain technology. The decentralized Internet has the advantage that data and information can be decentralized and managed by individuals without depending on specific companies or administrators. This is the basic idea of the proposed method.

In the following section, research background is described followed by the proposed method. Then, some of simulation studies are described followed by conclusion with some discussions.

II. Research Background

A. Blockchain

A block that stores information = a hash function (which replaces some data with a certain other random string: this replacement makes it impossible to read the original data from the string, acting as a cipher) where a hash function is a function that calculates input data in a fixed procedure and outputs a character string of a fixed length regardless of the length of the data of the input value. This research assumes SHA-3: Secure Hash Algorithm 3 as the hash function. This is because there is no regularity between the input data and the output hash value, and if the input data is even slightly different, a completely different hash value is output. In addition, it is difficult to guess input data that gives a specific hash value (weak collision resistance), and it is not easy to find other input data with the same hash value (strong collision resistance). In addition, it is a method of connecting blocks of data that are equally connected without management in the center of the block and that have been replaced with hash values. The basis of the networking method is the P2P method, which manages data.

When it is wanted to mine to add a new block, encrypt the transaction with a hash function and check the consistency with the previous block before adding. Mining is the issuance of a new block, and this issuance must be confirmed by the computer calculations involved in the blockchain to be consistent. Confirming consistency requires astronomical calculations, and all nodes participating in the blockchain participate in the calculations to confirm consistency.

One of the characteristics of blockchain is that it is resistant to attacks because there is no central administrator. In addition, a huge number of computers are involved in the procedures carried out on the blockchain, and they are also encrypted. If the information is tampered with, the hash value will be replaced, and it will be known that all the nodes in the world have been tampered with. Since the information is distributed and managed, there is no need to centralize it, and the more people who participate, the cheaper the operation becomes.

Governance is also an issue for blockchain. This is the problem of how to design and make decisions that affect the design to securely and stably record and process transactions on the blockchain. There is also the issue of scalability. A public blockchain is a distributed ledger with an unspecified number of participants, so the throughput (processing speed) is slow. In addition, there is the issue of privacy. Since the ledger of information traded on the blockchain is public, anyone who participates in the network can see the transaction information. Therefore, in order for blockchain to be implemented in society and spread widely, it is necessary to ensure the confidentiality of sensitive transaction information.

Tapyrus is one of the publicly available blockchain tools. Anyone can freely participate in this blockchain network and can create and view transactions. On the other hand, since the authority to generate blocks and add functions belongs to the administrator network, the governance problems of conventional public blockchains can be resolved.

Tapyrus clarifies the domain to which the blockchain is applied, and multiple federations (coordinators) can be configured by the stakeholders of the domain. In addition, the consensus algorithm used for block generation can be multi-signed by federation instead of Proof of Work (PoW) adopted by Bitcoin and Ethereum. This ensures consistent and stable approval of transactions. Furthermore, since anyone can participate in node operation and the ledger information is open to the public, the reliability of the public blockchain can be guaranteed. Next, a block verification method will be described. It is necessary to clarify the domain to which blockchain is applied. Select multiple federations (coordinators) from domain stakeholders. Construct a signature network that realizes block generation by “multisignature” by 2/3 of the federation (parameter adjustable). The signing network blocks transactions transferred to the Tapyrus network and broadcasts the created blocks to the Tapyrus network. Network participants will then verify the validity of the blocks created by the transaction and signature network.

Colored Coins were developed as part of the Bitcoin 2.0 project (handling Bitcoin as financial assets such as securities and bonds, assets such as commodities and real estate, and expressing this asset information in colors). Besides the underlying cryptocurrency that maintains the Tapyrus chain, it can support the operation of issuing, canceling, and transferring arbitrary tokens designed with unique value by network participants. This includes support for data provision by Oracle, and Tapyrus will support data provision by a trusted third party (Oracle) to enable the execution of smart contracts conditional on real-world data.

Two important features are introduced here. Atomic Swap and Extension Chain. The former is a technology that enables peer-to-peer exchanges between two cryptocurrency tokens on different blockchain networks, and Tapyrus can support coin/token exchanges between chains with features based on atomic swaps. . In addition, by making the unique functions of various blockchains mutually usable, participants can implement the necessary functions at any time. Also, Extension Chain is a mechanism that adds specific functions to the blockchain without changing the first layer, and only the participants who need the functions bear the additional overhead. This avoids the centralization of the network and the burden of data not directly related to transactions by network participants, which could have been caused by implementing the first layer to handle all needs in the past.

A feature of transactions using blockchain is that all transaction histories are recorded in a block (ledger). When dealing with, huge storage and throughput are required. In addition, with a proprietary protocol that uses an accumulator, a large amount of transaction data is compressed and recorded in each block, thereby solving storage and throughput problems, which was difficult until now without compromising security. Enables massive data transactions.

“Paradium” is a blockchain traceability application. “Paradium” is an application that can manage the movement of large amounts of goods (massive transaction volume) by solving problems of storage and throughput by installing Tracking Protocol using Accumulator developed by

"Chaintope". It is possible to implement the traceability function of blockchain not only on private chains that are managed independently, but also on public chains that do not have a central administrator. It is possible to safely manage the movement of goods using blockchain technology not only for one company but also between companies or across industries.

Tapyrus version 0.5.0 is now available for download[1]. Tapyrus v0.5.0 is supported on three platforms: Linux, MacOS and Windows (WSL). Introduce new opcodeOP_COLOR (0xbc) to allow issuing/sending/destroying arbitrary tokens in Tapyrus. OP_COLOR is based on OP_GROUP, which was previously considered for introduction in BCH, with some improvements, and has the following functions.

- Token issuance.
- Issuing reissue able tokens.
- Issuance of non-reissue able tokens.
- Issuing NFTs.
- Sending token.
- Incineration of tokens.

B. Web3.0

Blockchain has affinity with Web3.0 and decentralized applications. Web3.0 (Web3) was proposed by Gavin Wood, co-founder of Ethereum in 2014. It consists of a web system built in a distributed manner instead of the conventional centralized one. It refers to an ecosystem where Blockchain is the underlying technology. Gavin Wood proposed the notation Web3. Initially, Web 3.0 was the Semantic Web advocated by Tim Berners-Lee of W3C, that is, the Web that allows computers to collect information and make decisions autonomously, but this concept has spread to the general public. Web 3.0 and Web3 have come to be equated because they were not.

There is "Infrastructure mode" which is one of the operation modes that can be performed with a wireless LAN. To use the wireless LAN environment, install a router that serves as an access point. Installing an access point enables Internet communication via wireless LAN. Wireless LAN is not limited to Internet communication. In a wireless LAN environment, communication between terminals using the same LAN is possible. The function to communicate between terminals using the same LAN is called infrastructure mode.

On the other hand, "Ad hoc mode" is also one of the operation modes of wireless LAN, but it is a paired function with infrastructure mode. In ad-hoc mode, terminals communicate with each other without using an access point. In ad-hoc mode, communication is encrypted using the WEP method, but because the security standard is older, the risk of being deciphered is higher than in infrastructure mode, where communication is encrypted in a more complicated format. In infrastructure mode, files can be shared faster than in ad-hoc mode. Infrastructure mode is also superior in terms of ease of setup, so there aren't many benefits to using ad-hoc mode from now on.

When communicating between terminals in ad-hoc mode, the Internet cannot be used while files are being shared. In infrastructure mode, the Internet can be used even while terminals are communicating with each other. Ad-hoc mode allows only one-to-one communication, but infrastructure mode allows one-to-many communication. A single computer can communicate with multiple devices at the same time.

There are no major disadvantages to infrastructure mode, but the following three points should be noted.

- Need to prepare an access point.
- A compatible router is required.
- Peripheral devices must support wireless LAN.

To use infrastructure mode, installation of a wireless LAN router that will act as an access point is needed. Note that one-to-many communication is not possible without a wireless router. In addition, any wireless LAN router is not sufficient, and a model that supports infrastructure mode is required.

In the ad-hoc networking, terminals that can communicate using infrastructure mode are not limited to PCs but can also be used with various peripheral devices.

III. Proposed Method

The network architecture is based on IEEE 802.11s. Wireless ad-hoc mode is a method for wireless devices to directly communicate with each other. Operating in ad-hoc mode allows all wireless devices within range of each other to discover and communicate in peer-to-peer fashion without involving central access points.

On the other hand, blockchain technology is a type of database that directly connects terminals on an information communication network and processes and records transaction records in a distributed manner using cryptographic technology. Blockchain has a mechanism that can easily detect falsification of data by using encryption technology such as "hash" and "electronic signature". Blockchain has a mechanism that can easily detect falsification of data by using encryption technology such as "hash" and "electronic signature". In addition, although an unspecified number of participants conduct transactions in blockchain, many participants (not necessarily all participants) record copies of everyone's transaction history, so some computers may go down. However, the entire system does not go down, as many of the remaining participants continue to keep records. Since the copy of this transaction history cannot be deleted, the transaction record once recorded remains as evidence without disappearing. A system in which data is distributed among many participants is called a distributed system.

Many distributed systems to date have had a central administrator for the system. However, in blockchain, all participants continue to copy transaction history autonomously. This is called an autonomous decentralized system and can be said to be one of the major features of blockchain. The characteristics of this autonomous decentralized system, which

[1] https://github.com/chaintope/tapyrus-core/releases/tag/v0.5.0

does not allow fraud or tampering and stably records the history of fair transactions, has been indispensable for transactions that require high credibility, such as cryptocurrencies.

Essentially, networking for the block chain, therefore peer-to-peer based networks. The proposed method is applicable to the block chain networking even for the network nodes are moving devices. Furthermore, the mobile devices can be moved from one to the others. Even so, the network connectivity can be maintained. Therefore, the method works well for block chain networking.

The network situation is illustrated in Fig. 1 where MPP: mesh portals, MP: mesh point, AP: access point, MAP: mesh access point, STA: pure client station.

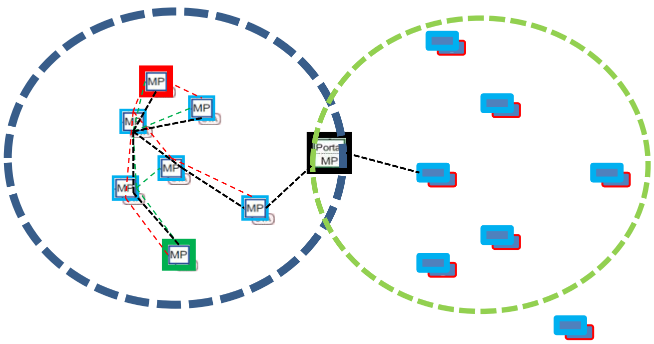

Fig. 1. Network situation.

The followings are situations,

1) Each Node has direction, speed, move with distance.
2) Each Node will sense path to others (same area) for send DATA.
3) Each node will keep path to Agent for send DATA (to other area).
4) Agent is special Node (unlimited Energy).
5) Agents become relay to other area.

Research focused on three bottom layers of the OSI model. In the physical layer was air (wireless medium) and the followings are set-up in the Data Link layer (Interface),

1) Node addressing.
2) Packet transmission / re-transmission,
3) Buffer receives / transmit,

The followings are also set-up in the Interface with Link,

1) Network layer (Data Handler),
2) Route calculation *weight criteria,
3) Path determination,
4) Packet examination,
5) Fragmentation / de-fragmentation,
6) Packet re-formation,

When nodes do communicate with others, they will use other node as relay (if destination located far away). The number of relays will determine hops. Relay will receive, process, and transmit packet. Relay will calculate the best route to next relay / node. Transmission will follow sequential process (from node to node until destination). Source and destination (*also agents) will maintain end-to-end communication (TCP communication type) as shown in Fig. 2.

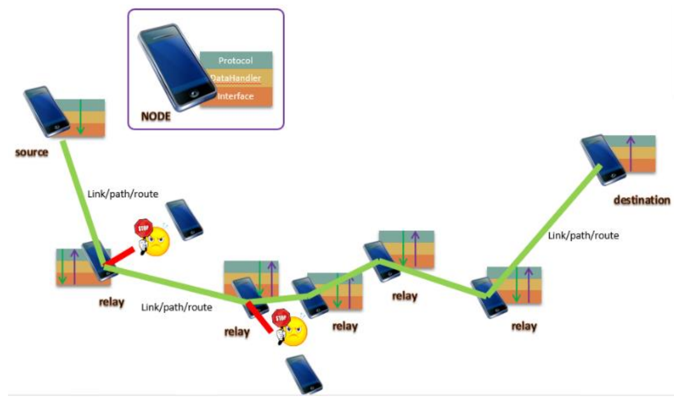

Fig. 2. Communications among the nodes.

Node to node communication is done in accordance with the following steps,

1) Broadcast to get neighbor's knowledge,
2) Broadcast to send packet to next node,
3) Receive messages (packet, reply/Hello, etc.) from the other node, examine it, and process it,
4) During data transmission, each node must follow point to point communication type.

a) In this situation, error transmission through wireless medium is considered. Bit error happen when source sent bit 'b' and receiver doesn't receive 'bit' b. Bit error rate (BER) shows the probability of bit got error. Typical value of BER for electric link was 10-9, and for optical link was 10-12. Source of error: EM interferences, loss signal, hardware failure and memories error during the path route, etc. In this simulation, BER was set to zero. Also, there is no detection and correction scheme.

Duplex link is assumed as shown in Fig. 3. Packet here imitated IPPacket. On each packet, there were:

- HEADER*.
- Source and destination.
- Flags (to mark packet with certain purpose).
- TTL (time to live).
- Type of protocol used*.
- Detection error CRC*.
- Source hop and destination hop.
- DATA (real transmission goal).

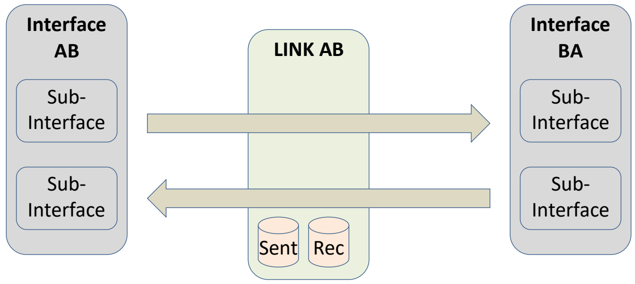

Fig. 3. Assumed duplex link in the simulation model.

There are assumptions made in IPPacket creation. Packets are treated as follows,

- IPPacket formation (executed in Protocol layer).
- IPPacket encapsulation/de-encapsulation.
- IPPacket queue.
- IPPacket transmission (unload/reload source hop and destination hop).
- IPPacket fragmentation / de-fragmentation.
- IPPacket re-formation.

Furthermore, packet formation is as follows,

DATA in BYTES (which intended to be sent).

Header information.

Protocol TCP.

Source and Destination.

Length.

ID.

TTL (time to live).

Source HOP and Destination HOP.

Flags.

Encapsulate DATA within IPPacket.

Packets are transmitted as follows,

Sender Station A:

When IF, send it out; Start Tout timer for this IF,

Wait for Tout (Time-out value) for ACK,

If (ACK) Then clear timer; proceed to next transmission,

Else backoff for a random number of Tout intervals; retransmit; If no ACK after repeated transmissions, give up.

Receiver Station B:

If (CRC(IF) OK && DA(IF) == address(B), send ACK,

If may be damaged by noise or by another station transmitting at the same time (collision).

Any overlap of frames causes collision.

Packet Framing is done as follows,

Responsible for: reliable transmission of frame through Link.

Determine complete packet receiving.

Error detection: CRC check.

Error recovery: retransmission of packets.

Live time of packet exceeded.

Selective ARQ (Automatic Repeat Request).

Boundaries of frame:

Character oriented framing.

Length counts – fix length.

Bit oriented protocols (flags) *used.

Also, Bit Oriented Framing: BOF (Flag) is assumed as follows,

Flag is (actually sequence of bits) that used to indicate the beginning and end of completed packet.

Together with fragment_offset, sequence of fractioned packet can be determined.

Standard protocol used bit sequence of 8 01111110 as ONE flag.

INVENTED ~ 1970 by IBM for SDLC (synchronous data link protocol).

Packet fragmentation means break up the data into smaller pieces. This is necessary when the maximum transmission unit (MTU) is smaller than the packet size. For example, the maximum size of an IP packet is 65,535 bytes while the typical MTU for Ethernet is 1,500 bytes. Since the IP header consumes 20 bytes (without options) of the 1,500 bytes, 1,480 bytes are left for IP data per Ethernet frame (this leads to an MTU for IP of 1,480 bytes). Therefore, a 65,535-byte data payload (including 20 bytes of header information) would require 45 packets (65535-20)/1480 = 44.27, rounded up to 45 as shown in Fig. 4. On the other hand, Fig. 5 and 6 show packet transmission in send and receive, respectively.

Meanwhile, as shown in Fig. 7, route / path calculation can be done as follows,

Stated as Table_routing.

Used 3 criteria: buffer on next hop, distance (*RTT), and direction of next hop (getting closer or away).

Buffer and distance made throughput weight on the link.

Route decision is executed in DataHandler layer.

Table_Routing is shown in Table 1. In the table, the followings are detailed assumptions,

Node_address: address of Interface in next hop.

Interface: set Interface must be used to reach next hop.

RTT: round trip time.

Throughput: throughput calculation for link.

Direction: + (getting closer), - (getting away).

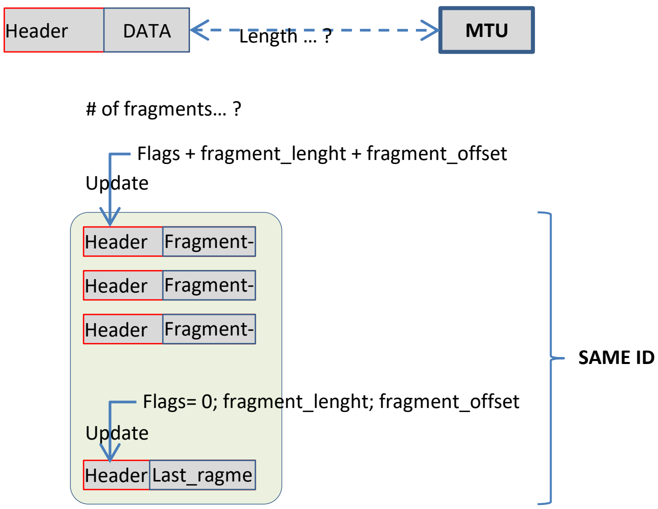

Fig. 4. Packet fragmentation.

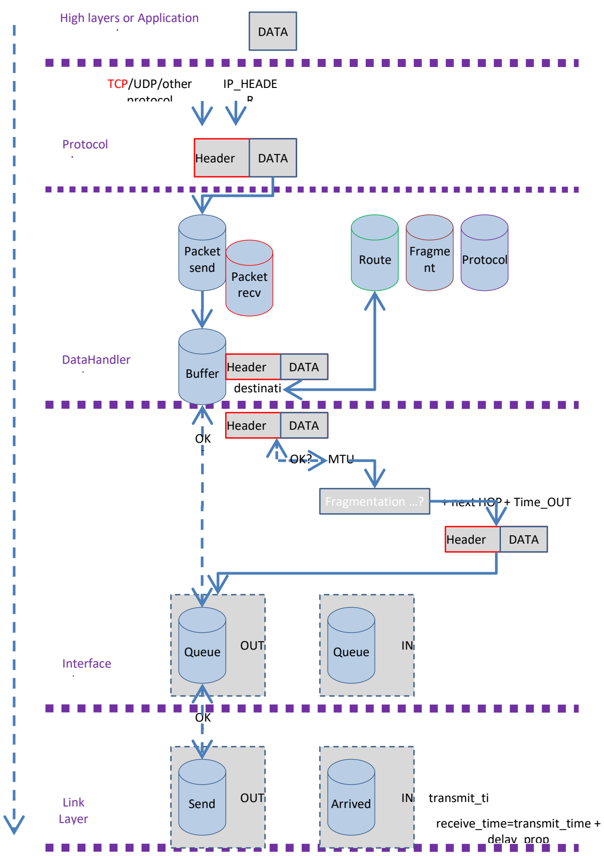

Fig. 5. Packet transmission (send).

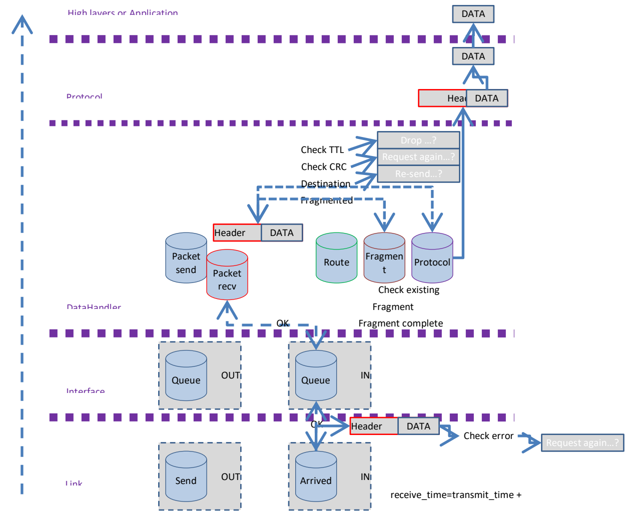

Fig. 6. Packet transmission (receive).

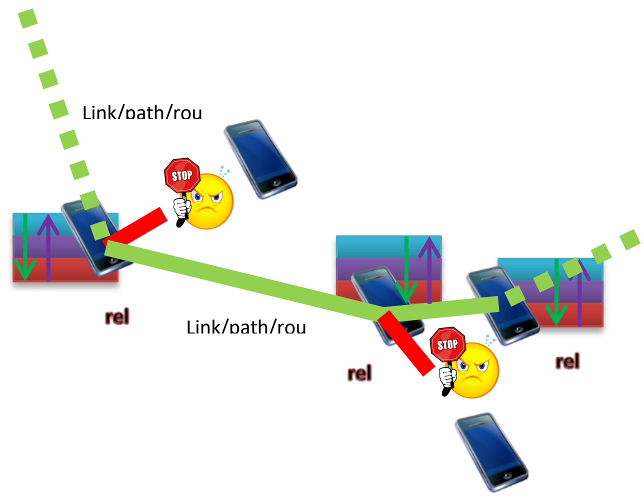

Fig. 7. Route / path calculation.

TABLE I. ROUTING TABLE

Node_address	Interface	RTT	Throughput	Direction
192.168.0.2	ABIface	b ms	1000 Bytes/ms	+
192.168.0.20	ATIface	t ms	8000 Bytes/ms	-
…				

Energy can be calculated as follows,

1) Node dissipates Eelec = 50 nJ/bit to run the transmitter or receiver and ϵamp = 100 pJ/bit/m^2 for the transmit amplifier.

2) To transmit a k-bit message a distance d, the Node expends:

3) To receive the message, the Node expends:

4) The communication range of the nodes is a perfect symmetric unit disk. If dx,y ⩽ rx → then Node-x and Node-y can see each other.

IV. Simulation Studies

Node Deployment is shown in Fig. 8 and is assumed as follows,

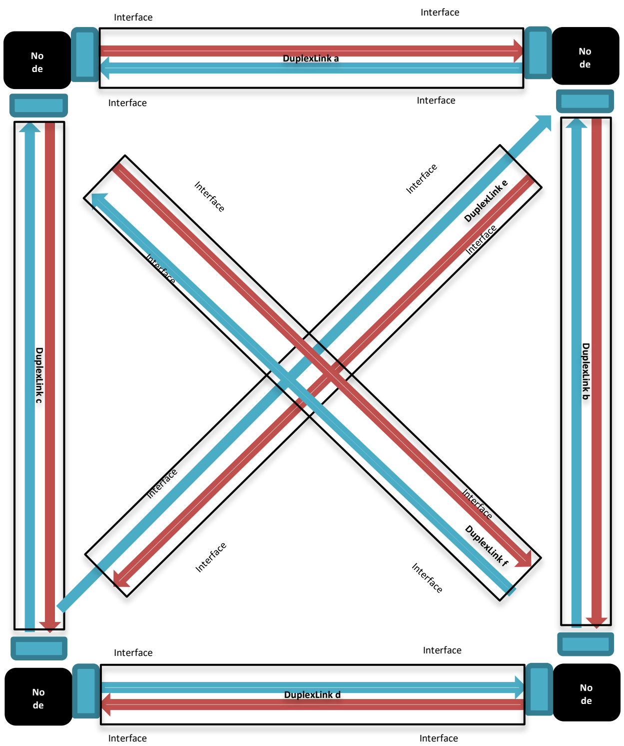

Fig. 8. Node deployment.

1) Each node examines itself and senses its neighbors.

2) Nodes create object Interface (with #Interface equals to #neighbors).

3) Ex. Node A has Interface AB, AC, and AD.

4) Interface AB is read as Interface at Node A that can reach Node B. Interfaces at a Node have same address.

5) Every Interface (in Node) is related with object Link (#Link equals to #neighbors).

6) Ex. Node A connected with Link "a", Link "f", and Link "c". Link "a" was used by Interface AB; Link "f" was used by Interface AC; Link "c" was used by Interface AD.

7) Nodes calculate buffer, RTT, and throughput through each owned Link.

With these, Node forms a routing table.

route 1:192.168.0.2; Interface_AB; RTT; throughput; 0.

route 2:192.168.0.3; Interface_AC; RTT; throughput; 0.

route 3:192.168.0.4; Interface_AD; RTT; throughput; 0.

In the simulation study, the following 25 nodes and 4 initiators are considered as shown in Fig. 9.

Initiator node is node that initiates transmission of packet. Like other nodes, initiator is always moving with random direction, speed, and distance as shown in Fig. 10.

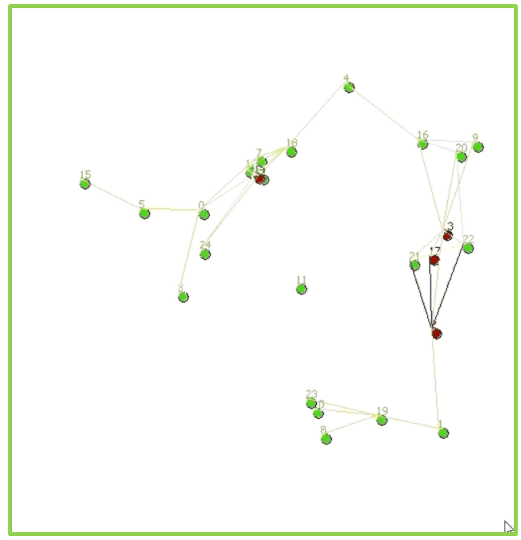

Fig. 9. Network configuration.

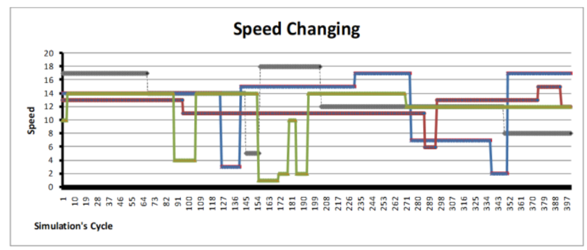

Fig. 10. Packet transmission speed.

V. Conclusion

Method for Ad-Hoc blockchain of wireless mesh networking with agent and initiate nodes is proposed. Minimizing the number of hops and maintaining connectivity of mobile terminals are concerns. Through simulation studies, it is found that increasing number of initiator nodes caused nodes to route a large number of messages. Thus, these nodes will die out quickly, causing the energy required to get the remaining messages to increase and more nodes to die.

This will create a cascading effect that will shorten system lifetime. Multi-hop routing, however, imply high packet overhead, (more nodes in the network means more hops will be available). The packet overhead of the multi-hop routing is extremely high compared to single path routing since many nodes near the shortest path participate in packet forwarding. This additional overhead caused by moving node can cause congestion in the network.

The idea of a "decentralized network", which is the greatest feature of Web 3.0, may change the existing corporate form. That is the birth of the decentralized autonomous organization "DAO". A DAO is an organizational form without a centralized administrator. Because it is an organization operated by a program on the blockchain, it has the advantage of being extremely transparent. In addition, since there is no top, it is managed democratically, such as by voting when deciding something, and the direction is decided by the party that wins the majority. The proposal method that can build this block chain ad-hoc can contribute to promote Web3.0.

VI. Future Research Works

Further investigation needs to be conducted on dynamic routing advantages and factors which affect routing mode, e.g., flow type, delay, and etc. The throughput/delay/reliability tradeoff between wireless network areas that deploy agents and without agents is also investigated.

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