New Enhanced Performance MAC Routing Algorithm to Improve Reliability in Multimedia Data Transmission based on Mutual Diversity for Optical Networks

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Abstract
Requirements for increasingly complex, scalable, and dynamic networks, which provide assured end-to-end connectivity in a wide range of scenarios, have been emerging. In this context, we have been investigating Optical Networks that provide extremely high data rates makes it a very attractive medium for multiservice transmission in building networks at low cost. Recently, there has been active research going on congestion control in optical networks to provide the communication reliability and bandwidth efficiency. We investigate the mutual diversity technique as a candidate solution for congestion control over Optical Network. This paper proposes a new robust medium access control (MAC) protocol, called Mutual Diversity MAC (MD-MAC), which exploits the mutual communication capability at the physical (PHY) layer to improve robustness in optical networks. In MD-MAC, each terminal proactively selects a consort for mutual operation and lets it pass on concurrently so that this mitigates interference from nearby terminals and thus improves the reliability of network and its bandwidth efficiency. It has been evaluated through extensive simulations with very establishing results, particularly on highly congested scenarios where the load balancing capabilities of the protocol becomes highly significant. For meticulous evaluation, this study presents and uses a realistic reception by taking Bit Error Rate (BER), and the corresponding Frame Error Rate (FER) into consideration.

Index Terms
Mutual Diversity, Optical fiber communication, Medium Access Control protocol, Bit Error Rate (BER), Frame Error Rate (FER), Bandwidth efficiency.

I. INTRODUCTION

Optical communication networks play a vital role in today's
internet world as they offer huge competence in utilization of large bandwidth available on the optical channel. Wavelength Division Multiplexing (WDM) technology epitomized the optical communication by increasing the capacity in by several orders of magnitude. Signal attenuations in static and fixed network and interference are the two major obstacles reduce the potential in delivering signals through optical networks. Conventional routing layer solutions support the mutual delivery of information by selecting intermediate routing nodes for a given source destination pair. But, it may be difficult to maximize the performance till all the routing nodes are coordinated to cooperate at lower levels. Because the network capacity is always determined by the fundamental MAC and PHY layer protocols. For example, consider a *carrier sense* (CS)-based *medium access control* (MAC) protocol. A routing node is regarded as a greedy challenger to other nodes as they compete with each other to grab the shared medium, interfere in each other's communication and cause collisions. Also incurs energy wastage by rendering them to overhear.

Mutual MAC algorithms are the hotspurs in active research in the field of the data transfer. For example, in *Mutual - MAC* [2], cooperating routing nodes are determined in a proactive manner and are used to forward frames at higher bit rates. The endeavor is to deliver frames at a faster rate by utilizing multi-rate capability at the same instant, improve the communication reliability in interference-rich environment [11]. *Mutual communication* at the PHY layer [5] directly enhances the link reliability; mutual communication exploits miscellany offered by multiple users, known as *multiuser* or *mutual diversity*. It results a dramatic improvement in *bit error rate* (BER), which leads to improve the link reliability, the primary incentive of mutual diversity as mentioned in this paper.

The proposed MD-MAC maneuvers on a single channel and uses a single consort. Each transmitter sends its signal along with its consort in a mutual manner to improve the communication reliability. The important aspect of MD-MAC is the selection of *consort, as* each routing node monitors its neighbors and dynamically determines a single consort as that one exhibits the best link quality.

This paper enhances the MD-MAC algorithm in two ways.

(i) In the MD-MAC algorithm, a sender and its consort mutually transmit a frame whenever the sender

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experiences a transmission failure [10]. If it is due to the interference, it assists as the communication becomes more robust in the presence of channel error. This is incorporated in the enhanced MD-MAC protocol presented in this paper.

(ii) The MD-MAC assumes to exchange two short control frames (RTS and CTS) before transmitting a data frame, which is not usually the case. However this paper employs the two control frames optionally in order to increase performance.

The proposed MD-MAC algorithm has been evaluated via simulation using ns-2 [10]. Most of previous researches only concentrated on evaluating BER, but this paper evaluates system-level performance such as packet delivery capability. BER and *Frame Error Rate* (FER) statistics are used as an evaluative parameter. This is the first kind of study on *mutual communication* that offers elemental system-level comparisons with the BER and FER in optical networks as per the knowledge of the author. The End-to-end packet delay is evaluated for MD-MAC. Performance variation due to the changes in fiber noise level has been observed to analyze the MD-MAC. It shows a best performance consistently regardless of the fiber noise level. Effect of network traffic in terms of varying number of communication sessions and varying packet rate has been measured in order to understand the scalability of MD-MAC in optical network.

The rest of the paper is organized as: Background and system model are summarized in Section II. Section III presents the proposed MD-MAC protocol; the four-way handshaking algorithm and the consort selection mechanism. Performance study and evaluation results are discussed in Section IV. Finally, conclusions are drafted in Section V.

II. BACKGROUND AND SYSTEM MODEL

One of the efficient MAC schemes is MD-MAC which makes use of PHY layer allying for reliable communication.
The system model assumed throughout this paper is explained in this section.

A. Mutual Diversity

Diversity techniques such as co-located optical routing nodes can mitigate the interference problem by transmitting redundant signals over essentially independent channels. However, due to the physical size and hardware complexity, it may not be always feasible in practice for each node to have multiple transmitting light sources. Recently, a new class of diversity techniques called *mutual diversity* has been proposed, in which the routing nodes interact with each other to jointly transmit information exploiting diversity offered by multiple users [4],[17].

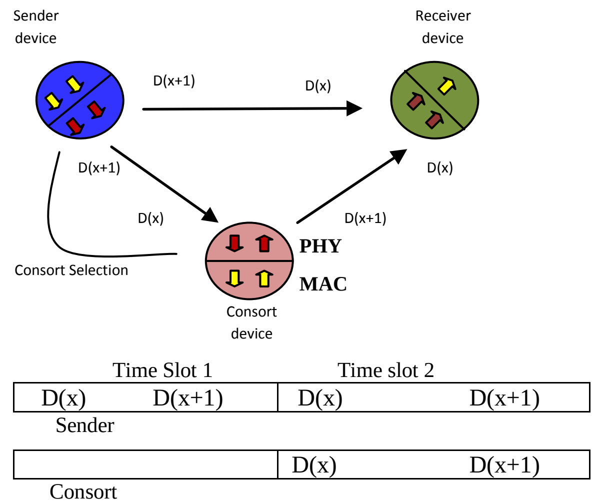


Fig. 1 Mutual communication using a single channel.

There are two types of mutual diversity algorithms: *repetition-based* and *mutual operation based* algorithms [7]. The transmission of multiple copies of a data stream is disseminated among the cooperating routing nodes. Consider a simple three routing node example with a sender, a consort and a receiver device as in Fig. 1. In time slot 1, the sender device transmits two symbol blocks, D(x) and D(x+1), to the consort. The sender and its consort mutually transmit the blocks in time slot 2 as in the figure. It is not only possible for both the sender and the consort to transmit concurrently on the same channel but also improves the reliability of the communication.

B. Mutual Diversity in Optical Networks

The communication link reliability is the very important factor in optical networks at noisy and unstable environments. In case of disseminated *automatic repeat request* mechanism, a source and distributed repeater nodes concurrently transmit the same data frame repeatedly till the source correctly receives an acknowledgement from the destination [11]. This mechanism enhances the communication reliability at the cost of more power dissipation, more routing overhead, and more network traffic, and consequently results in the reduction of network throughput.

In the research of *Mutual MAC* (M-MAC), four control frames such as *Relaying Start* (RS), *Relay Acknowledgement* (RA), *Relay Broadcasting* (RB) and *Transmission Start* (TS) are defined in addition to conventional *Request-To-Send* (RTS), *Clear-To-Send* (CTS), and ACK. When a DATA frame is transmitted using mutual diversity, all control frames are transmitted through the conventional *Single-Input-Single-Output* (SISO) link. This results in unreliable delivery of control frames, limit the applicability of this protocol. Directional knowledge of consorts is required for routing in this method.

According to the concept of Virtual *Multiple-Input-Single-Output* and multiple consorts supported MAC protocol, a *Single-Input-Single-Output* path between a source and a destination is exposed using an routing protocol like *Dynamic Source Routing* (DSR) [18] and multiple consorts are selected by exchanging periodic *one-hop hello* packets. The source and its consorts mutually transmit to an intermediate node which is several-hop away on the routing path. The drawback of this algorithm is, for successful cooperation, the receiver must have at least *k* consorts when the sender uses *k* consorts. All the concepts mentioned above are different from the proposed MD-MAC like they use multiple channels [9], [17] where as MD-MAC operates on a single channel and is consistent with the standard routing layer protocols.

C. Signal Propagation and Reception Model

Data stream propagation within a optical fiber channel is characterized by means of three effects: *attenuation* due to distance between the sender and the receiver, *dispersion* due to the manufacturing defects of the fiber and *scattering* due to collision of photons in a multipath propagation [4]. To successfully receive a transmitted data stream two conditions have to be satisfied. First, the receiver must be within the periphery of the sender, that is the received signal power must be equal or larger than the *receive threshold*. Second, the received signal power must be strong enough to overcome the influence of the noise and interference. This condition is described by the following *Signal-Interference-Noise Ratio* (SINR) model.

$$\mathrm{SINR} = \frac{P_r}{N + \sum_{i \neq r} P_i} \geq Z_0$$

Where, P_r is the received signal power, P_i denotes the received power of other signals arrived at the receiver, N is the effective noise at the receiver, and Z_0 is the minimum required SINR, commonly called *Capture Threshold*. As signal reception in real-life environment is not deterministic, a smaller SINR increases *Bit Error Rate* (BER) and thus a communication could fail with a higher probability.

III. MUTUAL DIVERSITY MAC (MD-MAC)

In an optical network, many nodes are spread over a network area and communicate with each other using multi hop pathway rather than direct communication in the mutual communication to increase the reliability as well bandwidth efficiency.

A. Consort Selection and its Propagation

Technological advancement in the field of optical communication has unearthed the solutions for the above mentioned problems. The following operation decorum has been employed in the proposed MD-MAC:

- The RTS/CTS exchange is normally disabled.
- Each node (A) maintains $n_{A,B}$ for each possible neighbor, which is the number of consecutive communication failures.

It is incremented when A's transmission to B fails and is reset to zero when it is successful.

- On the other hand, the RTS/CTS exchange is used only when a sender (A) experiences transmission failures at least once with a consort neighbor (B) in the recent past. It can also be explained as, it is enabled when $n_{A,B}$ is larger than a certain threshold (n_{th}), which is called *RTS probing*, commonly used

in multi rate adaptation protocols [10], [17]. Fig. 3(a) shows the four-way handshaking in the MD-MAC protocol.

- No mutual communication is rendered for RTS and CTS control frames as in Fig. 3(a) because transmission failures of those short control frames are usually due to collisions. This should be contrasted with the simple scheme in Fig. 2(a), where the mutual communication is applied to every frame including RTS and CTS.

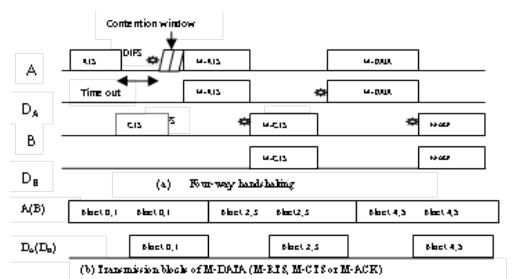


Fig. 2 A simple mutual scheme with consorts D_A and D_B on a weak link (A, B). (SIFS – Short interference space, DIFS- Inter frame space.)

Mutual communication is used for DATA and ACK frames in case data transmission failed, but subsequently the RTS/CTS exchange was successful.

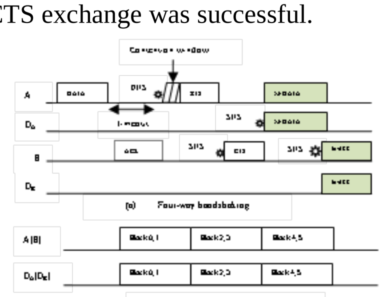


Fig. 3 MD-MAC with consort D_a and D_b on a weak link (A, B). (RTS is usually not used in MD-MAC but it is used in Fig. 3(a) because the preceding communication failed).

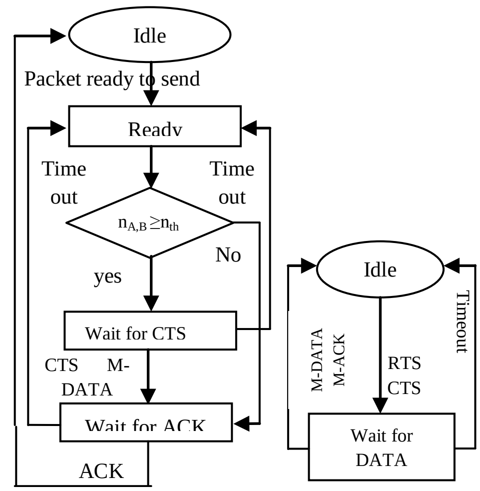
• Transmission of symbol blocks in MD-MAC is projected in Fig. 3(b). Comparing to the transmission scenario shown in Fig. 2(b), time slot 1 for the symbol blocks of M-DATA (M-ACK) is skipped and thus, the frame transmission time is not larger than the original DATA (ACK). This is possible because frame from node A doesn't have to repeat the original symbol blocks unlike in Fig. 1 and Fig. 2(b). However, the first two symbol blocks can optionally be transmitted for the synchronization purpose between A and D_A. Regarding the ACK frame, D_B as well as B receives M-DATA and thus D_B can generate M-ACK as well.

Fig. 4(a), 4(b) and 4(c) illustrates the state transition diagram for the sender, the receiver and the consort, respectively. In Fig. 4(a), if n is smaller than n_{th}, the RTS/CTS exchange is skipped because the prior communication is successful and the communication environment is free from channel errors. No mutual communication of DATA will be initiated. In other hand, the RTS/CTS exchange will perform the data communication and DATA transmission occurs concurrently with its consort. Fig. 4(b) shows the state transition diagram of a receiver. Fig. 4(c) explicit the state transition of a consort of node A. Since node A can be either a sender or a receiver, the figure includes both state transitions. As a transmit consort (*i.e.*, node A is a sender), it will mutually send M-DATA when it hears RTS from A as well as CTS to A. As a receive consort (*i.e.*, node A is a receiver), it will mutually send M-ACK when it hears RTS to B, CTS from A and M-DATA from A. It is shown on the right hand side in Fig. 4(c).

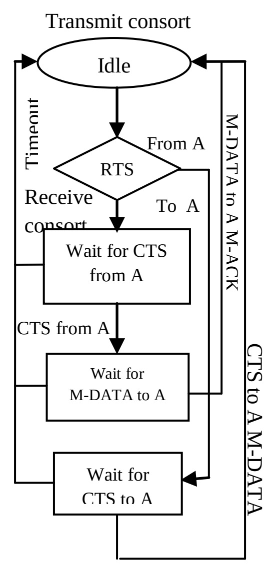
B. Consort Selection and its Propagation

In order to perform the mutual transmission in MD-MAC, each and every node should opt for its consort by monitoring or overhearing its neighbors with respect to *link quality*. Among all neighbors, the neighbor with the best link quality is chosen as its consort. There are three reasons behind this choice: (i) Communication between a node and its consort must be highly reliable. (ii) A consort with the best link quality is most probably the closest node. (iii) It ensures that the sender and the consort share the same communication environment so that they can make a consistent decision on cooperation. The mutual diversity can be effective when a node and its consort are spaced at least $\lambda/4$ apart, where λ is the wavelength.

SINR, *distance*, *load*, *interference level* and *Signal Strength* are some factors used to indicate link quality. Here, SINR is preferred as it takes noise and interference into account and is measurable with no additional support. When a sender does not hear any further frames from the chosen consort, the corresponding binding expires. In addition to this, when a sender hears a frame from a different node that exhibits a better link quality, it employs this node as a new consort.



(a) Sender (b) Receiver



(c) Consort (of node A)

Fig. 4 Flow chart for State transitions of a sender, a receiver and a consort.

Once a consort is determined, each node must inform to the chosen consort with all the frames it transmits. For this purpose, it uses an address field (Addr4) in MAC frame as in Fig. 5 so that its neighbors as well as the selected consort become to know about the selection. MD-MAC does not require any data format changes. A sender and a consort transmit the exactly same copy at the MAC layer while they are different at the physical layer. When the node does not have a frame to transmit for an extended period of time, it will broadcast a hello frame, the format follows M-DATA, with the destination (Addr1) and the source (Addr2) to be the transmitter itself.

Mutual communication may face three important situations. They are: (i) What if the consort does not cooperate when it should? (ii) What if the consort cooperates when it shouldn't? and (iii) what if two different senders select the same consort? Consider the example, where D_A and D_B are the consorts of node A and B, respectively. When $n_{A,B} \geq n_{th}$ and the RTS/CTS exchange is successful, node A will send M-DATA. When node D_A does not receive either the RTS or the CTS, it does not attempt to send M-DATA together with node A. But, this situation does not do any harm and does not violate the semantic of MAC protocol and there is no algorithmic ambiguity.

The second case happens when node A sends an RTS and node B replies with a CTS, which is successfully received by node D_A but not by node A. It may cause confusion because node D_A transmits M-DATA but node A doesn't. Any way, it doesn't do any harm. Node A will retransmit the same frame, which is a duplicate frame for node B. Such duplicate frames can be filtered out within B's MAC based on the original functionality, called *duplicate packet filtering*. This algorithm matches the sender address (Addr2 in Fig. 5) and the sender-generated sequence control number (SC) of a new frame against those of previously received ones. If there is a match, the receiver transmits ACK but ignores the duplicate frame.

Consort conflict is the third case. When two senders select the same consort and transmit concurrently, what should the consort do? In this situation mutual communication is attempted only after the successful exchange of RTS/CTS in MD-MAC. Hence, when both senders wish to transmit data frames mutually, they already have exchanged RTS and CTS successfully with their corresponding receivers concurrently. Consort is in proximity to both senders and will participate in the mutual transmission of one of the two senders but will not be able to participate on behalf of the other sender. This is the case where the consort does not participate when it should. This does not make trouble as explained above.

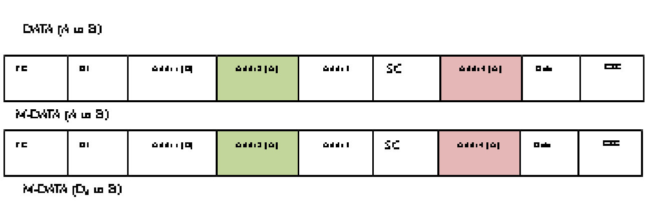


Fig. 5 Format of MPDU frames for DATA and M-DATA in the MD-MAC protocol. FC: Frame control, DI: Duration/ Connection ID, SC: Sequence control, Addr3: Address of basic serviceset or BSSID)

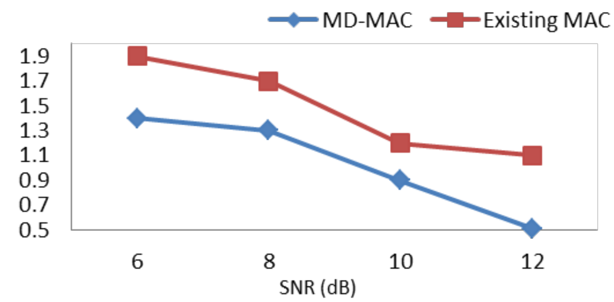
IV. PERFORMANCE EVALUATION

The performance of the proposed MD-MAC protocol is evaluated in comparison to the conventional method using ns-2 [10]. Section IV-A introduces the realistic reception model we have proposed in this paper and Section IV-B explains the simulation parameters. Simulation results are presented in Section IV-C.

A. Signal Reception in the Modified Ns-2

The signal reception model implemented in ns-2 is based on three fixed PHY parameters, *i.e.*, *carrier sense threshold* (CSThresh), *receive threshold* (RxThresh) and *capture threshold* (CPThresh). They were introduced in Sections II. When a frame is received, each node compares the received signal power against CSThresh and RxThresh as explained in Section II-C. If it is smaller than CSThresh, the receiver ignores the signal. If it is in between the two thresholds, the receiver considers the medium busy as but does not receive the signal (frame in error). While it is higher than RXThresh, the receiver receives the frame. However, when the node receives another signal during receiving the first signal, their ratio is compared against CPThresh. If the ratio is larger than CPThresh, the stronger signal survives (if it is the first one) and the weaker signal is dropped; otherwise, both frames are considered failed. This deterministic reception model based on the three thresholds serves reasonably well when evaluating high level protocols such as network and transport layer algorithms. However, when evaluating lower layer protocols, it is important to simulate a more realistic reception model. We modified ns-2 network simulator [10] to take *bit error rate* (BER) into consideration when determining the success or failure of a received signal. It is based on the following 3-step process: (i) Compute SINR, (ii) look up the BER-SINR curve to obtain BER, and (iii) calculate *Frame Error Rate* (FER) and determine whether to receive or drop the frame.

First, SINR is calculated based on the equation introduced in Section II-C. According to that equation, the effective noise N is one of key parameters that determine SINR. In this paper, we first compute the thermal noise level within the channel bandwidth. According to the well known noise density of -174 dBm/Hz, it is -101 dBm. Assuming a system noise figure of 6 dB, the effective noise at the receiver is -95 dBm. It is assumed that the environment noise is fixed to be -83 or -90 dBm in this paper and that fading is contained in the noise.

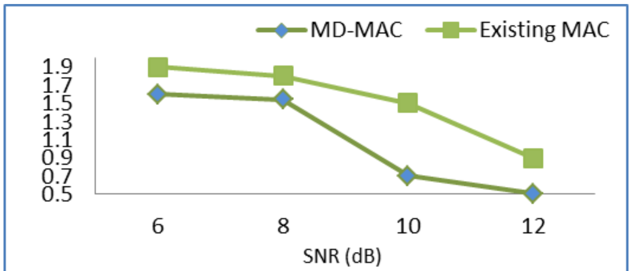


(a) BER versus SINR

Table 1 Parameter configuration of Simulation 1(BER)

SNR(dB)	BER of existing MAC	BER of MD-MAC
6	1.9	1.4
8	1.7	1.3
10	1.2	0.9
12	1.1	0.5

Second, the BER-SINR curve used in our simulation study is obtained. The BER-E_b / N_0 curve is converted to the BER-SINR curve based on the relationship SINR=E_b / N_0 × R/B_r, where E_b is energy required per bit of information, N_0 is noise (plus interference) in 1 Hz of bandwidth, R is system data rate, and B_r is system bandwidth that is given by B_r = R Cooperation reduces the required SNR by about 5 dB for the same BER. A frame consists of *physical layer convergence protocol* (PLCP) *preamble*, PLCP header and payload (data), and they may be transmitted at different rate. Hence, since BER is a function of SINR and modulation method as well as the mutual diversity, it should be calculated separately for the three parts of a frame.



(b) FER versus SINR

Table 2 Parameter configuration of Simulation 1(FER)

SNR(dB)	FER of existing MAC	FER of MD-MAC
6	1.89	1.6
8	1.8	1.53
10	1.5	0.7
12	0.9	0.4

Fig. 6 BER and FER comparison of the MD-MAC with the existing MAC in optical transmission.

Third, once BER is obtained, FER can be calculated, which determines the percentage that a frame is received correctly. For example, given α-bit preamble, β-bit PLCP header and γ-bit payload with BER of p_a, p_b, p_c respectively, FER is obtained by $1-(1-p_a)^{\alpha}(1-p_b)^{\beta}(1-p_c)^{\gamma}$. FER without cooperation is much higher than that with mutual diversity and that's how mutual communication improves the reliability of an optical link. In summary, FER is not deterministically but probabilistically determined based on SINR in our simulation, making our evaluation more realistic and meaningful.

B. Simulation Environment

It is assumed that 50 nodes located over a square area of 300 × 1500m^2. Each simulation has been run for 900 seconds of simulation time. The propagation channel of *optical fiber* is assumed with a data rate of 1 Mbps. The environment noise level of -83 or -90 dBm is modeled as a Gaussian random variable with the standard deviation of 1 dB. Noise level of -90 dBm is considered ignorable and interference from other transmitters dominates. On the other hand, noise level of -83 dBm is used to simulate a harsh communication environment.

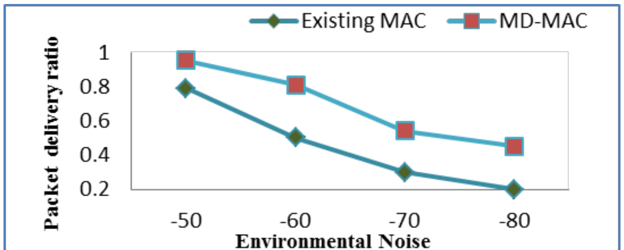
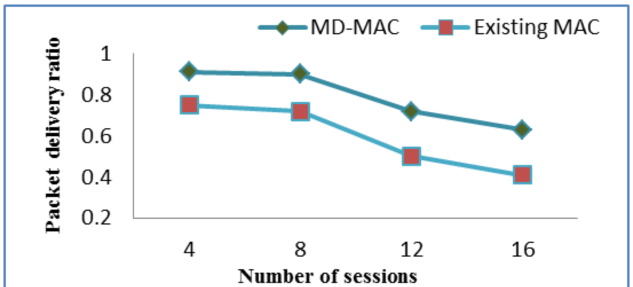


Table 3 Parameter configuration of Simulation 2(Environmental noise)

Environmental noise (dBm)	Packet delivery ratio of existing MAC	Packet delivery ratio of MD-MAC
-50	0.79	0.95
-60	0.50	0.81
-70	0.32	0.54
-80	0.21	0.45

Fig.7 Impact of Environmental noise.

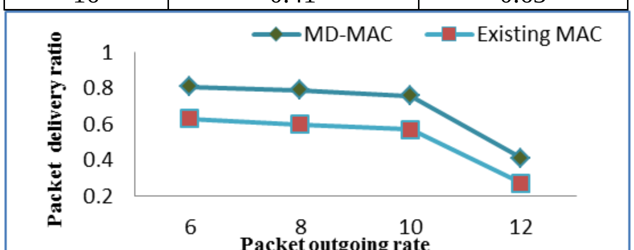
Four constant bit rate (CBR) sources transmit UDP-based traffic at 2 packets per second and the data payload of each packet is 512 bytes long. Source-destination pairs are randomly selected. Routing protocol is used to discover a routing path for a given source-destination pair. Performance metrics are *packet delivery ratio*, *average end-to-end delay*, *route discovery frequency* and *cooperation ratio*. (i) The packet delivery ratio is the ratio of the number of data packets successfully delivered to the destination over the number of data packets sent by the source. (ii) The average end-to-end delay is the averaged end-to-end data packet delay including all possible delays caused by buffering during route discovery, queuing delay at the interface, retransmission delays at MAC, propagation and transfer times. (iii) The route discovery frequency indirectly refers to the number of route failures because a source node is supposed to discover a new routing path if an existing one does not work. This happens when any one of the links of a multi-hop path breaks. Link breaks caused by unavoidable due to unreliable communication environment and it can be overcome, which is in fact the main theme of this paper. (iv) Finally, the cooperation ratio refers to how often nodes mutually transmit frames in MD-MAC. Since MD-MAC attempts to use the existing method whenever possible, it is interesting to know how often it succeeds and how often it resorts to mutual communication.



(a) Varying the number of sessions

Table 4 Parameter configuration of Simulation 3(Number of Sessions)

Number of Sessions	Packet delivery ratio of existing MAC	Packet delivery ratio of MD-MAC
4	0.75	0.91
8	0.72	0.90
12	0.50	0.72
16	0.41	0.63



(b) Varying the Packet rate

Table 5 Parameter configuration of Simulation 3(Number of Sessions)

Packet outgoing rate	Packet delivery ratio of existing MAC	Packet delivery ratio of MD-MAC
6	0.63	0.81
8	0.60	0.79
10	0.57	0.76
12	0.27	0.41

Fig.8 Effect of network traffic on packet delivery ratio.

A. Simulation Results and Discussion

The simulation results of MD-MAC are shown and discussed in this session. Fig.7 shows the *packet delivery ratio* (PDR) of existing technique and MD-MAC with two environment noise levels of -90 and -83dBm. As shown in the figure, MD-MAC consistently outperforms existing technique but the gap becomes more significant (53~73% increases) when the environment noise is high (-83 dBm). This is because noisy environment makes optical link less reliable and mutual diversity is usefully exploited in MD-MAC in this case. However, the same trend has been consistently observed in other simulation-based studies including [17]. This is due to the complex interplay among MAC and routing layer protocols.

Less route discoveries in MD-MAC have been observed in comparison to existing technique , it is reduced by 22~50% and 35~69% with the noise level of -90 and -83 dBm, respectively. This clearly tells that the path or link reliability is improved significantly with MD-MAC. MD-MAC eliminates around half of the *false alarms* caused by link breaks due to collisions and thus helps reduce the control overhead for finding new routing paths.

Nodes in MD-MAC cooperate only when a primary link does not work. When the environment noise level is high (-83 dBm), the cooperation happens more frequently to survive the harsh communication environment. It is easy to understand that the cooperation ratio is about 20% (or 40%) when the environment noise is -90 dBm (or -83 dBm). Because still there are number of unreliable links exist in the network for example due to inter-node interference.

To see the impact of noise in more detail, the packet delivery ratio with the different environment noise levels of -90~ -74 dBm is shown in Fig. 7. While the performance decreases sharply in a noisier environment, MD-MAC consistently performs better than existing technique and the gap widens as the noise increases. Network traffic is one of the most important system parameter. Fig. 8 shows the effect of network traffic in terms of the number of sessions and the packet rate. During the simulation, two network traffic factors of 4 sessions and 2 packets per second are applied as default values. It is clear that, the performance is degraded with the increased network traffic. In particular, the performance quickly drops when the traffic increases beyond a certain threshold i.e. 14 sessions and 8 packets/sec in the simulation as shown in Fig. 8(a) and 8(b) respectively. This is because the network overhead is rapidly increased beyond the threshold and becomes congested. However, MD-MAC still outperforms and this effect is more significant in the harsh environment of -83 dBm.

V. CONCLUSIONS AND FUTURE WORK

This paper proposes a solution through *mutual diversity MAC* (MD-MAC) protocol and discusses design issues and performance benefits in optical networks. When a communication link is unreliable, a sender transmits its signal together with its consort delivering the signal with greater reliability. In order to select a consort, each node sleuths its neighbors with respect to link quality by receiving periodic hello packets and overhearing ongoing communications. The proposed MD-MAC is designed based on the IEEE 802.3 network architecture without requiring any changes in frame formats. According to the system-level simulation results, MD-MAC significantly outperforms the conventional IEEE 802.3 standards, particularly in a harsh environment. As a future work, exploiting mutual diversity based on multi-channel interfaces will be investigated. Development a mutual diversity-aware routing algorithm is a forthcoming attainment. Cross-layer approach is expected to dramatically boost the network performance because it gives a progression to exploit other advantages of mutual communication such as lengthening the transmission range in addition to improving the link reliability. More efficient consort node selection is yet another important future prospective.

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