

DISTRIBUTED MULTICHANNEL MANUFACTURING AUTOMATION PROTOCOL NETWORK

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Abstract

Advances in computing and other technologies have produced a significant and rapid increase in the demand for new communication services. The Distributed Multichannel Manufacturing Automation Protocol (DMMAP) is a high speed LAN. It used the multichannel technique to aggrandize the network bandwidth, and used the distributed control policy instead of the centralized control of MMAP (Multichannel Manufacturing Automation Protocol). In this paper, we discuss the DMMAP how to manage many simultaneously received tokens and how to decide which MAC frame should be transmitted first.

INTRODUCTION.

Advances in computing and other technologies have produced a significant and rapid increase in the demand for new communication services. Especially in the real time system, local area networks (LANs) are required to provide not only high channel throughputs but also to satisfy stringent delay requirements. To meet these increasing demands, it is essential that future LANs be capable of operating at much higher data rate, achieving high channel efficiencies and lower delay [6]. The DMMAP, a high speed LAN, is a unslotted LAN scheme using a dual-bus or tree architecture in physically as fig. 1, and using a multichannel architecture in logically as fig. 2. The development of DMMAP based on Manufacturing Automation Protocol (MAP) using the standard IEEE 802.4 token passing bus was adopted by many companies in the manufacturing world, so the DMMAP is fully compatible with MAP. Besides its additional modem, amplifier powers are economical because it just needs two transmitters to send the data and MAC (Medium Access Control) control frame.

In 1989, H. H. Sung [1] has described the MMAP network that using the technique of frequency division

multiplexing (FDM) to provide the multichannel in broadband coaxial cable system. However its architecture must exist a headend working as centralized controller for channel arrangement. This organization will make a problem called "hot spot problem," since all transmitted frames in different channels must be processed by a centralized network headend, so the bandwidth of that headend must have a multiple of anyone channel transmitting data rate. This is difficult to make an infinite bandwidth headend! The DMMAP used the multichannel technique to aggrandize the network bandwidth, and used the distributed control policy instead of the centralized control of MMAP, that policy has no "hot spot problem."

There are some puzzles in DMMAP. The first is how to manage many simultaneously received tokens. The second is how to decide which MAC frame should be transmitted first for smoothing the system operation. In this paper, we have solved these problems by extending the length of response window, giving the priority of MAC control frames, and keeping the token that can service the highest priority data frame. They will be described by below discuss.

Section 1 surveys the system architecture, logical ring maintenance, and priority mechanism of conventional MAP network. The network topology, station architecture, channel management, and ring maintenance of MMAP network are introduced in Section 2. Section 3 discusses the system design consideration, component function, dynamic assignment mechanism, system maintenance, and priority mechanism.

1. MAP NETWORK

The MAP using the standard IEEE 802.4 token passing bus defines a broadcast protocol that determines which station on the bus can transmit its packets by holding token. A station

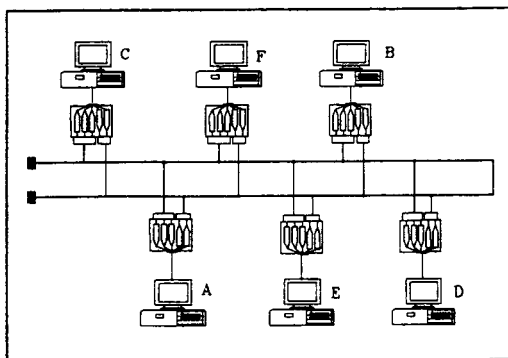


Figure 1. The physical topology of DMMAP network.
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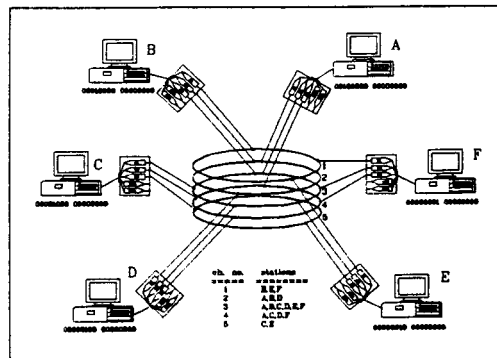


Figure 2. The logical topology of DMMAP network.

has the right to transmit its packets as long as it holds the network token, and every station on the network has the faculty to correct the network error conditions such as multiple tokens, lost tokens, token passing failures, failing receivers or transmitters, and duplicate station-addresses. This means that no special "monitor stations" are required, so it is a really distributed control system.

MAP networks normally utilize coaxial cable as the transmission medium and operate in either a broadband mode [3] or a modified baseband mode known as carrierband [4] [5]. During steady state operation, the token is passed from the highest addressed station in the network to the next highest addressed station, in descending order of address to the lowest addressed station, then back to the highest addressed station. This circular passing of the token forms a logical ring [2]. The various procedures use for handling the management of the logical ring, such as initialization, adding new station to network, and passing token.

2. MMAP NETWORK

The MMAP network based on the principle of frequency division multiplexing (FDM) is proposed to control the channel number to transmit message and decrease the average message deliver time. The topology of MMAP is the same as figure 3. On each channel there is a headend. Each channel can split into two parts: up link and down link. Station transmits message at up link frequency to headend. Headend receives message at up link frequency and transmits the received message at the down link frequency. All stations are turned to down link frequency for receiving messages. Every station can transmit and receive at different channel at the same time. The logical ring maintenance and channel management are described as below:

Ring initialization: When network is just initialized, the headend station should be the first station to turn on. Headend station will choose one channel at random (usually channel one) and turn on the headend associated with that channel. Now the network is active, headend station wait another

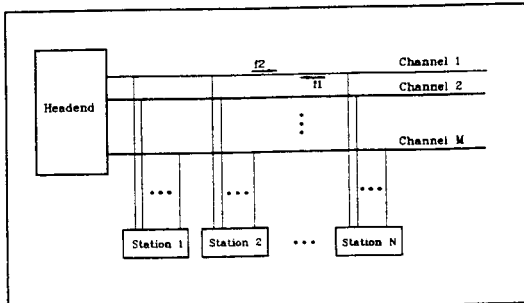


Figure 3. The topology of MMAP.

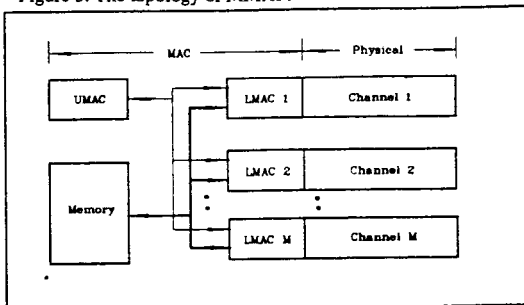


Figure 4. The network interface structure in MMAP network.

station to join the network.

Addition to ring: Any stations want to join to the logical ring, firsts open all the receiver to listen which channel is active, then try joining to those rings which channel are active. The step to add the ring on the separate channel is the same as MAP.

Deletion from ring: Suppose NS is the next station, PS is the previous station. When a station (TS) wants to quit from the ring, it should wait until it owns the token, then TS send a set_successor frame to PS, tell PS that NS will be its following station. After that, TS passes token to NS and quits from a ring. When a station quits from all logical rings, it finishes the entire deletion action.

Recovery: A number of error can occur. The error management method on each channel is the same as MAP.

Channel management: The number of channels is not permanent. When network throughput increases to a certain value, we increase the channel number. When network throughput is below a certain value, we close one channel.

The structure of network interface is only concern about MAC layer and physical layer in figure 4. It divides MAC layer into two parts: Upper MAC (UMAC) and Lower MAC (LMAC). The UMAC buffers the input/output message. There is only one UMAC. Each channel associate with one LMAC. LMAC is responsible for the token management and protocol at each channel. UMAC memory is partitioned into two parts: one for transmitting and another for receiving. Each part is composed by three components: frame descriptor (FD), buffer descriptor (BD), and data buffer.

3. DMMAP NETWORK

The DMMAP is real time system that insures the token will be received in an appointed interval, it causes the size of response window to increase when the channel number has increased. This phenomenon made a parabola characteristic of bandwidth v.s. channel number, but it has a linear curve at lower channel number [8]. The DMMAP provides a dynamic assignment mechanism that connects the group stations only, as fig. 2.

3.1 Consideration.

The IEEE standards do not directly correspond to the ISO/OSI model. The IEEE 802.4 token passing bus standard defines the physical and the medium access control (MAC) portion of the data link layer specification. It doesn't adapt to the requirement of multichannel network. Therefore the standard has to be modified at its MAC sublayer [1]. We divided its MAC layer into upper medium access control (UMAC) and many lower medium access control (LMAC) sublayers, as fig. 5.

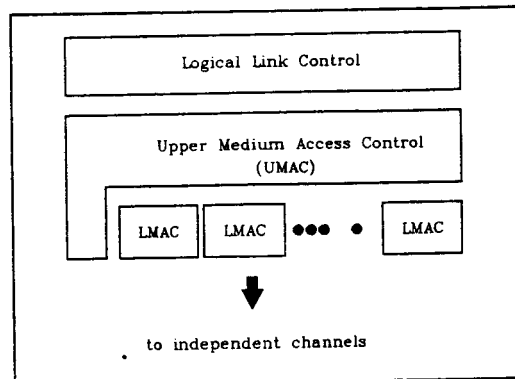


Figure 5. The DMMAP layer model.

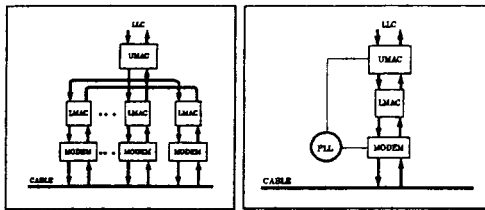
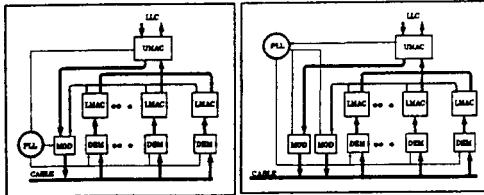


Figure 6 (a) model 1 (b) model 2



(c) model 3 (d) model 4

Each channel in DMMAP is fully independent and needs a private LMAC device in a station interface to service the channel's medium access control. Generally, a frame is transmitted on channel by modulation technique. In transmitter, it may be coded, for example, by duobinary coding, then modulated to some frequency channel by local oscillator. In receiver, the signal on the received channel is demodulated by local oscillator, and decoded to indicated form, then translated by LMAC. The modulation and amplify in transmitter are significant design factor since they need more electric power and generate more magnetoelectric disturbance and heat. In practice, the direct implement model that gives a transmitter and receiver per a channel as fig. 6 (a), isn't a good design way!

The other view is just using a transmitter and a receiver per station. In the station interface, there is a local oscillator which frequency is programmable to modulate the transmitting frames in transmitter and demodulate the frames in receiver, as fig. 6 (b). However, channels should be continually monitored by LMACs, so it will lose some important information and cause the protocol failure in this time-sharing scheme. The third view improves the above scheme. It increases the receiver number to equal with the LMAC's and remains with a transmitter, as fig. 6 (c). Since the electric power, cost, heat consumption, and magnetoelectric disturbance of receiver are insignificantly smaller than transmitter's, this scheme will save many implemented costs. The maximum length of data frame is eight thousand bytes more, but the length of most control

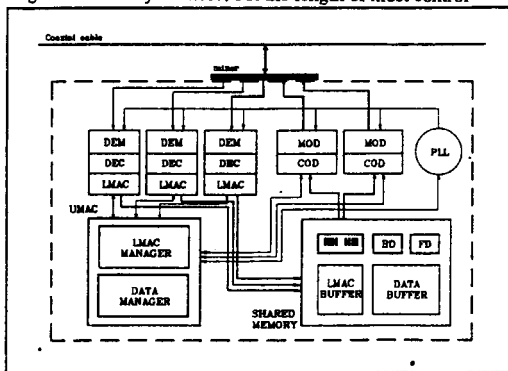


Figure 7. The Architecture of DMMAP network interface.

frames is below thirty hundred bytes. The control frames will wait too long, and may make some protocol failure condition. The last scheme replaces a transmitter with two transmitters, one is responsible for transmitting all data frames called "data transmitter (DTX)" and the other is responsible for transmitting all channel's MAC control frames called "control transmitter (CTX)," it remains the receiver number that is equivalent to number of LMAC, as fig. 6 (d).

3.2 Architecture overview.

Physically, the architecture of DMMAP is a linear or tree-shaped cable onto which the stations are attached, same as MAP network's. Logically, stations are attached to many independent rings (channels). In each ring, there is a token around that operates same as MAP's. The DMMAP using distributed control is no central control monitor. All stations on the network are compeer and all rings are independent to each other. Therefore any station may receive many tokens or transmit many MAC control frames simultaneously. The of DMMAP station interface consists of an UMAC, many LMACs, many receivers, and two transmitters, as fig 7.

The UMAC consists of DATA Manager (DATAM), LMAC Manager (LMACM), and shared memory. The DATAM is used to manage the data packets from or to LLC, and schedule them before transmitting or after received. The LMACM is used to arrange the simultaneous arrival MAC frames that came from LMACs and waited for passed to the CTX. In transmission, the UMAC sublayer accepts the packets from logical link control (LLC) sublayer, and passes it to a priority transmitting queue in the shared memory according the packet's priority. When any channel's token is arrival, the DATAM will pick the most priority data frame up, and pass it to DTX that tunes its frequency to that channel for sending. In reception, any LMAC receives a data frame from its monitoring channel, and passes it to a priority received queue according the frame's priority.

3.3 Transmitter, Receiver, and LMAC

The channels of DMMAP are fully independent of each other. In a station, every channel needs a private LMAC device to service that channel's MAC process. In transmission, the transmitting frame should be modulated to some frequency that is corresponding with the frequency of channel by FDM technique using a programmable local oscillator. In receiver, the frame on the each received channel will be demodulated by a specific local oscillator which frequency had been setting at the system installed.

The DMMAP station just has two transmitters, and it will not increase its transmitter number with the growing channel number. One for transmitting data frame called DTX, it picks up the data frames that sent from DATAM in the DTX queue, and transmits the frame to a channel that is assigned by DATAM. The other for transmitting MAC frame called CTX, it picks up the MAC control frames that sent from LMACM in the CTX queue, and transmits the control frame to a channel that is assigned by LMACM. The number of receiver is equivalent to the number of LMAC, but need not equal to the number of channel! The frame that has been demodulated by receiver will be passed to a priority received queue in shared memory when it is a data frame, or be passed to its LMAC for arbitration of MAC process. The process of LMAC is like as the MAP's process.

3.4 UMAC, LMACM, DATAM, and Shared memory

The UMAC is responsible for arbitrating contention of simultaneously multiple requests, such as transmitting multiple MAC control frames or accepted multiple data frames to or from different channels at one time. Besides the UMAC must avoid the longer waiting time of transmitted frame that

may make that frame oversleeping and loss its engagement. We discuss these topics as below:

A. DATAM: The DATAM is used to manage the data packets from or to LLC, and schedule them before transmitting or after received. There are four priorities (6,4,2,0) received queues and transmitting queues to buffer the priority (6,4,2,0) data frames that are equivalent access classes (7,6),(5,4),(3,2),(1,0) in LLC. The priority scheme of the DMMAP is like as scheme of MAP. This scheme allows the urgent messages to be transmitted first. There are many timers to maintain the mechanism of medium access control. We describe the manner of these timers using a sandglass diagram in the fig. 8.

The amount of sand in the sandglass expresses the amount of available time in which the station can transmit its data from the priority queue. The high priority token rotation time (HPTRT) is the maximum amount of time in which the station may transmit data from the highest priority queue. The token rotation time (TRT) is measured from the last time the stations hold the token to when the station receives the token privilege again. The target token rotation time (TTRT) for each of the lower three access classes (4,2,0) and one for ring maintenance, it is using to evaluate the available time of the lower access classes or ring maintenance by TTRT minus TRT. The available time of HPTRT, a constant value, had been loaded at initialized process. For limiting the network throughput, the TTRT setting almost follow the relation $TTRT_4 > TTRT_2 > TTRT_0$ [7]. Therefore the available time of these timers should be expressed as below :

$$HPTRT \geq (TTRT_4 - TRT) \geq (TTRT_2 - TRT) \geq (TTRT_0 - TRT) \geq (TRTR - TRT)$$

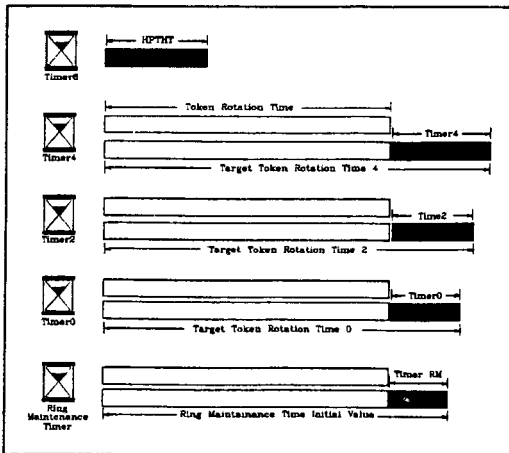


Figure 8 The timer of DMMAP.

The arbitrated strategy of transmitting queue with priority *i* is diagrammatized as fig. 9. If the available time of queue *i* has expired, then the DATAM will check to see whether the queue *i+1* has any available time to use. If the available time of queue *i+1* has expired too, then the DATAM will send the token back to the LMAC that attached on the token's channel as fig. 9 (a), otherwise the token will be passed to the queue *i+1* as fig. 9 (b), it is an abnormal condition. If the available time of queue *i* hasn't expired and there are no transmitting frames in the queue *i*, then the DATAM will check timer of queue *i+1*. If the available time of queue *i+1* has expired, then the token will be sent back the LMAC as fig. 9 (c), otherwise the token will pass to the queue *i+1* as fig. 9 (d). Let us consider a special case. The available time of queue *i* hasn't expired, and there have many frames in the queue *i*. At this time, another token has been received. However the DATAM

just can service a token at one time, so it will check which token can service the most priority transmitting queue. The DATAM will hold the token that services the most priority data frame, and send all other tokens back to their channels to keep the network throughput as fig. 9 (e).

This phenomenon of multiple tokens simultaneously arrived at a same station is called "token overlay" that will shorten the total bandwidth. A station on DMMAP network, which channel number is *M*, should increase its bandwidth in multiple *M*, but the token overlay that makes some token passed to successor before its timer expired shortens this time to *k* as fig. 10 [8].

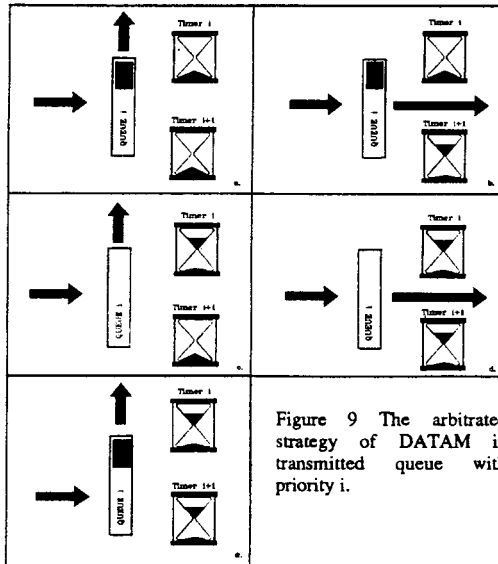


Figure 9 The arbitrated strategy of DATAM in transmitted queue with priority *i*.

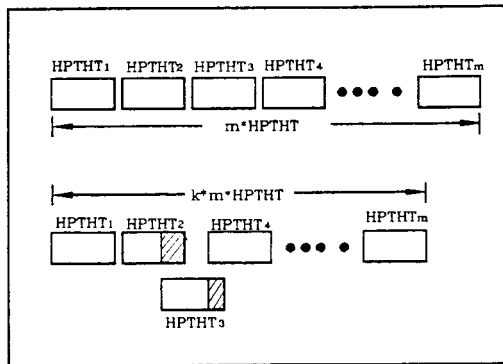


Figure 10 The example of token overlay.

B. LMACM: The LMACM is used to arrange the simultaneous arrival MAC frames that came from LMACs and waited for passed to the CTX. Many MAC frames may be submitted simultaneously, but the LMACM just can schedule one MAC frame to transmit at one time, so the other MAC frames must be queued in the waiting queue. In the fig 11, the MAC frame comes from one of LMACs, and enter into the corresponding queue of multiplex (MUX). At the same time, the priority of that frame moves into the corresponding buffer of controller of LMACM, then controller according its

schedule strategy to decide which frame should be pass to the queue of CTX, and increase the priority of the other frames. The priority policy of LMACM is transmitting the urgent MAC frame first. Its schedule strategy is (1) increase the priority of MAC frames in the waiting queue after every transmission. (2) according LMAC priority that set by interface's DIP when MAC frames have same priority. (3) select the most priority one of claim_token frames to increase its priority and keep the other's priority at one, when multiple claim_token frames are submitted. About the priority of MAC control frames will discuss below:

1. If a token frame stays in waiting queue too long, it will lose the real time characteristic of network, and make the idle timer of channel to be time-out. That will cause some stations to mistake that token has lost or the token holder has gone down, then a channel initialization process will be generated.
2. If the set_successor frame has been delayed too long, (1) it may lose to response the solicitation of solicit_successor_1 frame that will lose the chance of entering the channel, this is no matter of the network. This frame should be dropped by the LMACM when it has listened to the channel is non-silence. (2) It may lose to response the asking of the who_follows frame in time, and makes an unnecessary reinitialization, that will take some overhead to network. (3) It may lose to response the solicitation of solicit_successor_2 frame that will make the token to give up maintain the logical channel, that will take some overhead to network.

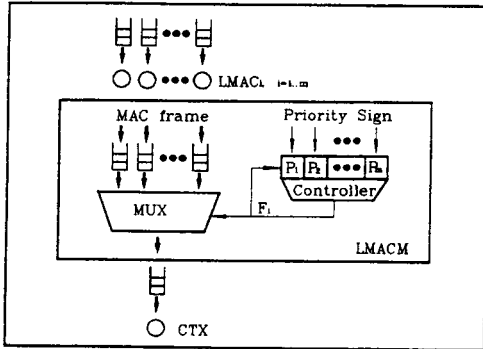


Figure 11 The LMACM configure.

3. If the solicit_successor_1 frame has been delayed too long, it will make some performance problem as that the token holder waits to transmit and takes the token with it. This frame should be dropped by the LMACM when the ring maintenance timer is time-out.
4. If the resolve_contention frame has been delayed too long, the station will give up the solicitation of solicit_successor_1 frame and pass the token to its successor when the ring maintenance timer is time-out, this is no matter of the network.
5. The who_follows frame, solicit_successor_2 frame, and claim_token frame are special frames, and seldom appear in the network, if that frames have been delayed too long, that will not matter of network.

From above analysis and according to the operation frequency of MAC frame, we give a MAC frame priority table, as fig. 12.

C. Shared memory: The shared memory is used to save the messages of CPU and UMAC. The shared memory includes the structure of a frame descriptor (FD), a buffer descriptor (BD), Data buffer, a UMAC private area and many LMAC private areas. The content of private areas of shared memory records the operating information to support the estimation of

LMACs and UMAC. The LMAC private records the information of channels. The UMAC private area records the information of station.

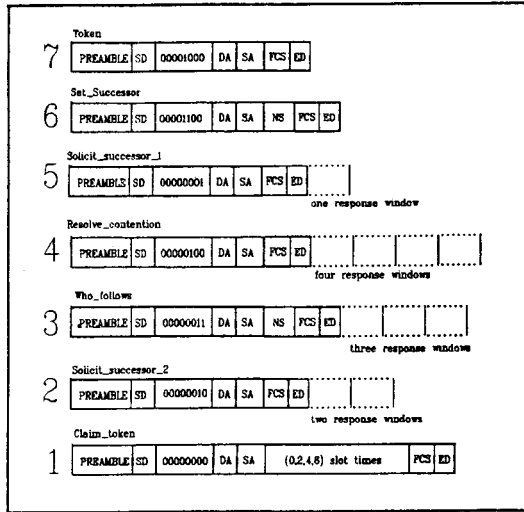


Figure 12. The priority of MAC frame.

3.5 Dynamic assignment mechanism

The DMMAP provides a dynamic assignment mechanism that connects the group stations only, as fig 2. it can expand its receiver number to increase the total network bandwidth, and get the faster communication speed.

CONCLUSION

The high speed LAN DMMAP adopts the traditional network configuration of IEEE 802.4, and its protocol is compatible with the existent protocol of IEEE 802.4. The network interface of station on the DMMAP is adjusted by expanding the receiver, LMAC, and transmitter to expand its total network bandwidth. The bandwidth will like linear growth with channel number when the number is below one hundred.

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