# A New WDM Network Architecture And Protocol Analysis for a Passive Star Topology

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*Abstract:* In this paper we study a new Wavelength Division Multiplexing technique, for a single-hope network using passive star topology. The new idea is based on the Multichannel Control Architecture (MCA) and on the number of data channels. In the new architecture, for each station corresponds a wavelength for data transmission. The MCA permits the distribution of control information over a number control channels that minimize the headers processing requirement at each station. This architecture in conjunction with the proposed transmission policy avoids data channel collision and improves the performance measures of the total network system. IMACS/IEEE CSCC'99 Proceedings, Pages:5621-5624

*Keywords:* wavelength division multiple access WDMA, multichannel, electronic processing bottleneck, receiver collision.

## 1 Model and Assumptions

The system under consideration as figure 1 shows is a passive star network. The system uses (v+N) wavelengths $\{\lambda_{c1,\ldots,}\lambda_{cv,}.\ \lambda_{d1}\ldots\lambda_{dN}\}$ to serve a finite number M of stations where M=N. The multichannel system at wavelengths $\{\lambda_{c1,\ldots,}\lambda_{cv}\}$ forms the MCA and operates as the control multichannel system while the remaining N channels at channels at wavelengths $\{\lambda_{d1}\ldots\lambda_{dN}\}$ constitute the data multichannel system. There is one to one correspondence among data channels and stations and for each data channel, $\lambda_{di}$, corresponds a unique station i. The Network interface unit NIU can be described as a $CC^v$-TT-$FR^v$-TR structure. It means that there are v control channels and each station has a tunable transmitter tuned at $\{\lambda_{c1,\ldots,}\lambda_{cv}\}$. The same tunable transmitter can be tuned at the dedicated $\lambda_{dk}$ to the station. The outcoming traffic from a station is connected to one input of the passive star coupler. Every station also uses v fixed tuned receivers one for each control channel and one tunable receiver to any of data channel $\{\lambda_{d1}\ldots\lambda_{dN}\}$. The incoming traffic to a user station is splitted into v+1 portions by a 1x(v+1) WDMA splitter as Figure 1 indicates. In our analysis the access method to MCA is based to the ALOHA protocol. The transmission time of a fixed size control packets is used as time unit (control slot) and the data packet transmission time normalized in control slot time units is L (L>1) which is called data slot. Control channels considered to be slotted with the size of the control packet. All control packets are synchronized in a parallel system constituting the control multislot. A station k desiring to communicate with an other, choose at random a control channel j, waits the beginning of the next multislot and sends first the control packet (header) over the $\lambda_{cj}$ channel. After the end of control packet transmission, the station transmits the corresponding data packet over its own $\lambda_{dk}$ channel without to be aware of any control channel collision (tell and go policy). The control packet is consisting of the transmitter address, the receiver address as is shown in Figure 1. If more than one control packets use the same control channel, during a control packet vulnerable period, a collision occurs (control channel collision). A station will hear the result of the transmission its control and data packet by listening to the star coupler multichannel system since it is operates as a broadcast medium. We assume that the total offered traffic from new generated and retransmitted control packets obeys to Poisson statistics. In the receiving mode if a station sees its address announced in a control packet, immediately adjust its receiver to the transmission wavelength channel, which is specified in the control packet for packet reception. We say that the tunable receiver of a station Z is active, if it is tuned receiving a data packet from a data channel of a $\lambda_{dk}$ (k=1,N). If the corresponding data packet of a successfully transmitted control packet is addressed to station Z and the receiver is active, the packet is rejected. This phenomenon is called receiver collision [3]. Also stations participating in unsuccessful transmissions defer their retransmissions for a random time until successful retransmission.

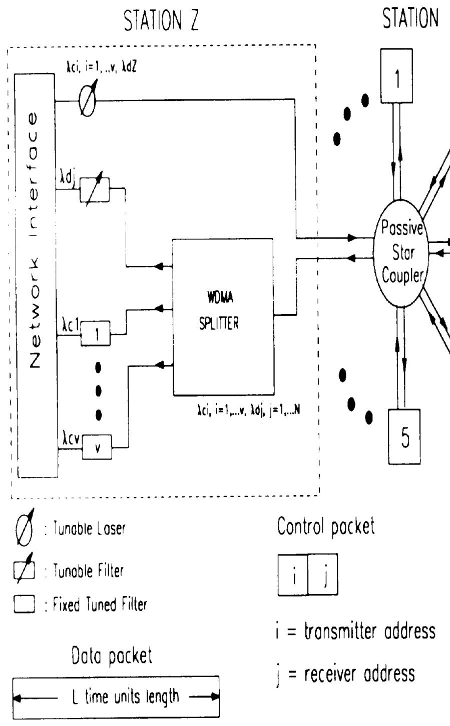


**Figure 1: Passive star multiwavelength control architecture, and packets structure**

## 2 Analysis

Let:

G = The mean offered traffic over (v-channel) control system in a multislot, that obeys to Poisson statistics.

$G_n = G/v$, the traffic to $j_{th}$ control channel $j \in \{1,\dots,v\}$ given that each control channel is chosen with equal and constant probability $P_j = 1/v$.

$P_c$= the probability of one Poisson arrival in a control channel during a multislot.

$$P_c = G/v \; e^{-G/v} \qquad (1)$$

$A_w$ = random variable representing the number of control packets in a multislot time $0 \le A_w \le v$. Thus the probability of finding $A_w = k$, control packets every one with one Poisson arrival during a multislot obeys to binomial probability low.

$$\Pr[A_w = k] = [\, v!/(v-k)!k! \,]\, P_c^{\,k} \, (1 - P_c)^{v-k} \qquad (2)$$

$S_c$ = The average successful transmission rate of control packets in a multislot time in steady state.

$$S_c = E\{ \Pr[A_w = k] \} = \sum_{K=1}^{\mathrm{Min}(M,v)} k \, \Pr[A_w = k] = G \; e^{-G/v} \qquad (3)$$

We define $P_f$ , the probability of successful (re)transmission of control packet over the control multichannel system. From (3) we take.

$$P_f = S_c/G = e^{-G/v} \qquad (4)$$

Let $G_d$, the offered traffic per data slot, per station.

$$G_d = LG/M \qquad (5)$$

Finally $S_{ds}$ the average successful transmission rate of data packets with destination a given station during a data slot time.

$$S_{ds} = G_d P_f = e^{-G/v} LG / M \qquad (6)$$

The throughput reduction induced by receiver collision is related with the probability a receiver to be active. Thus we examine what will happen if a data packet which starts transmission at time instant $t_r$ and has as destination a station Z who belongs to the set 1,2,…,M. It is obvious that if a successful data packet has started transmission between $t_r$ - (L-1) and $t_r$ - 1 will have activate the receiver of station Z and a receiver collision occurs. In the opposite case, the Z station tunable receiver will be able to read its destination address and the data packet is received correctly. Thus the tunable period lasts (L-1) time units. It is evident that any other successful data packet transmission, starting between $t_r$ + 1 and $t_r$ +(L-1), will find the station's Z receiver active and will be aborted causing receiver collision. In other words the collision window interval is extending from $t_r$ to $t_r$ +(L-1). The multichannel nature of the control communication system allows more than one successful headers transmission from different control channels to denote the same destination of data packets during the same time unit. Thus the station receiver is tuned only to one of incoming transmissions and rejects the others causing receiver collision [3]. In this case, there are different policies to select which packet is received correctly at destination. As an example we can say that the data packet that is transmitted on the lowest data channel win the competition. The probability that station Z is destination of a data packet is 1/M (for sake of simplicity of the analysis, we assume that a station may send packets to itself). We define the following events for the vulnerable period $t_r - (L-1) \leq I \leq t_r$.

$C_l$, the successful transmission of a control packet, in $j_{th}$ control channel $j \in (1,2\ldots,v)$, starting transmission in the $I_{th}$ -1 time unit of the vulnerable period.

$B_l$, the data packet staring transmission in the $I_{th}$ time unit, has as destination a given station, let's say Z.

Taking into account the independence of the $C_j$ and $B_l$ events for each time unit, we define A, as the event that no one data packet has as destination the station Z during the vulnerable period.

$$A = \bigcap_{l=1}^{L-1} \left( \bigcap_{j=1}^{v} \overline{C_j \cap B_j} \right) \tag{7}$$

We define as $P_{cor}$, the probability of correctly reception of a data packet from station Z starting transmission at the given time instant $t_r$. This probability is equivalent with P(A). From (7) we get,

$$\begin{aligned} P_{cor} = P(A) &= \prod_{l=1}^{L-1} \{ \prod_{j=1}^{v} [1 - P(C_j \cap B_j)]\} \\ &= \prod_{l=1}^{L-1} \{1 - P(B_j/(C_j)P(C_j)\}^v \\ &= \prod_{l=1}^{L-1} \{1 - [G e^{-G/v}]/(M v)\}^v \\ &= \{1 - [G e^{-G/v}]/(M v)\}^{v(L-1)} \end{aligned} \tag{8}$$

We define as throughput in steady state, the fraction of data packets that are received correctly at destination by a station during a data slot time.

$$S_M = S_{ds} P_{cor} \tag{9}$$

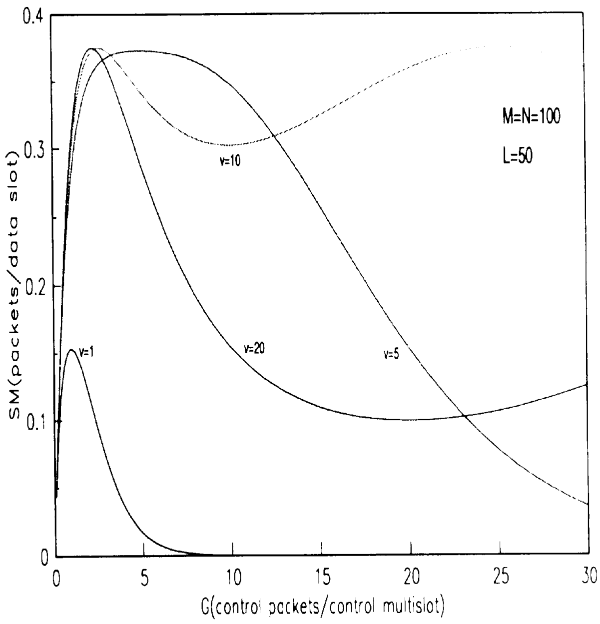


**Figure 2:The throughput SM per station versus the offered traffic G characteristics for v=5,20,30 (control channel) systems with L=50 time units and M=N stations/data channels**

Using approximations in the above equation, we take

$$S_M \approx [L\, G / M ]\, e^{-G/v}]\ \exp \{ -[G(L-1) / M ]\, e^{-G/v} \} \tag{10}$$

If we set the first derivative of equation (10) with respect to G equal to zero, we find the optimal value $G_{opt} = v$ that maximize the throughput . So

$$S_M(max) = [L\, v / M ] \exp \{-[1 + v(L-1) /(e\, M )] \} \tag{11}$$

If the above equation is differentiated with respect to v, can be found the of v for fixed values of M and L.

$$v_{opt} = [M / (L-1)]\, e \tag{12}$$

The proposed scheme among the others advantages avoid data channel collision, improving any more the efficient use of optimal bandwidth. Figures 2 shows that the throughput performance per station, approaches the maximum achievable value 1/e of the ALOHA protocols.

Each station fixed tuned receiver has only to process packet headers at a rate divided by a factor v(fixed tuned receivers number) compared with the single control channel communication system.

The main drawback of the proposed architecture can be considered the added cost of fixed tuned receivers at each station (more than one). Fixed tuned receivers are less expensive than tunable ones. The cost of setting up fixed tuned receivers is balanced with the profit of reducing the electronic processing bottleneck at the end station. On the other hand, the cost of devices is falling, so in the future having multiple transceivers at each station may become practical.

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