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On The Statistical Multiplexing of Optical Code Division Multiple Access

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Abstract- The aim of this paper is to contribute to the understanding of teletraffic behavior in optical code division multiple access networks. It explains a model of traffic capacity and its sensitivity to various parameters. Analytical model for OCDMA with and without call admission control were analyzed. However they have some disadvantage by ignoring the stochastic variation in circuit activity. It begin with the analysis of circuit switched OCDMA where circuit carrying bursty data. The analysis is independent of the OCDMA implementation or spreading code. In it considering a voice system which employs a power control and a variable rate vocoder. An OCDMA network has been taken where each user operates and can randomly access the network without the need of synchronization with respect to other user. It is assumed the circuit activity as a random variable and a class of networks which having different class of circuit activity. This has been shown that the traffic capacity of an OCDMA network is improved when circuit activity is a random variable and a heterogeneous data network is taken.

Index terms-Optical Code Division Multiple Access (OCDMA), Circuit activity, Queuing analysis.

I. INTRODUCTION

CDMA is an alternative multiple access technique to frequency division and time division multiple access. If the synchronization and power control problem are over come CDMA is very attractive to optical communication. In multiple access scheme the measure of its usefulness is not the maximum number of users that can be supported by the system but the peak load that can be supported by the system with a given quality and availability of service, measured by blocking probability, outage probability. In OCDMA channel are made up by giving a unique code word to each user that spread every user signal in time, frequency, phase etc. such that all user occupy the entire bandwidth simultaneously. In CDMA scheme both narrow pulse laser source and continuous wave laser source are proposed [1].Most pulsed source OCDMA technique used incoherent filter detector [2]. In all existing multiuser circuit switched system blocking occurs when all frequency slots or time slots have been assigned to a voice conversation or message for example in a wavelength routing network each user is assigned a unique wavelength channel as long as free wavelength channel are available after that new circuit request are blocked until a channel become free. In CDMA system each user share a common spectral frequency allocation over the time that they are active, hence new user can be accepted as long as receiver process to service them independent to time and frequency allocation [3] . In CDMA there is no hard limit on communication channel (i.e. code words) when spreading code of high cardinality are used. In CDMA performance is limited by the multiple user interference. As the spreading code are not truly orthogonal, it is difficult at the receiver to detect the signal exactly (maximize the autocorrelation and minimize the cross correlation due to multiple user interference), so bit error rate occurs. As the multiple user interference increases bit error rate increases and the performance degraded. When bit error rate increases the maximum threshold loss of information occurs. To overcome this problem we measure the outage probability of the network as a measure of service available.

In this paper the teletraffic model given in [4]has been used and taken a simple broad cast and select network with K subscriber i.e. K user that can connect to the network by accompanying a available channel, (wavelength in WRN and codeword's in OCDMA) by single optical fiber through combiner. At receiver part k receivers will be listening selectively to a particular channel by wavelength filtering or code correlation

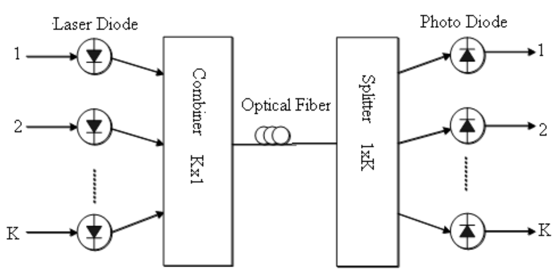

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Fig.1.KXK broadcast and select network

In conventional system a fraction of time or frequency slot must be set aside for users to initiating services and a protocol must be established for multiple requests when two or more user collide in simultaneously requesting services. In CDMA system even the user seeking to initiate service can share the common medium. They add up to the total interference and hence lower the total capacity to some degree.

In this paper teletraffic model of [5] is used. We defined the teletraffic capacity as the number of continuously transmitting circuits for which the performance measure are outage and blocking probability remains less than the maximum threshold. The channel capacity of CDMA system is analyzed in [6]. Most of the literature I traffic modeling in CDMA is based on the modeling of G/G/M queue. In practical switching network we assume that all the circuits are not transmitting data simultaneously, instead traffic is stochastic or each circuit carrying data for some interval only.

Suppose that the data stream transmitted in each circuit is busty in nature. As in [7] each circuit is carrying data with probability P and carrying no data with probability 1-P. Than circuit activity is defined as

$$circuit\ activity = \frac{T_{data}}{T_{data} + T_{no\ data}}$$

Circuit activity is highly dependent on the application generating data and for traditionally voice traffic circuit activity is 40%.Circuit activity is lower in data traffic in comparison to voice traffic [8]. It is beginned with the modeling of OCDMA without blocking and compares the aggregates carried circuit load with WRN, then used the call admission control and compute the load. The model is also analyzed with circuit activity as a random variable and a heterogeneous class network.

II. WRN and OCDMA model

A WRN model has been taken with k subscriber; Γ available wavelength can carry at most one circuit with circuit intra arrival rate having mean λ and exponential service time having mean μ. The number of circuit connected at any time T is a random variable with truncated binomial distribution [9]. Than number of circuit connected having probability P (N) is given by

$$P[N = n] = \frac{\binom{K}{n} r^n}{\sum_{i=0}^{\Gamma} \binom{K}{i} r^i}$$

An incoming call is blocked or call congestion when N > Γ is given by

$$P_{block} = \frac{\binom{K-1}{\Gamma} r^{\Gamma}}{\sum_{i=0}^{\Gamma} \binom{K-1}{i} r^i}$$

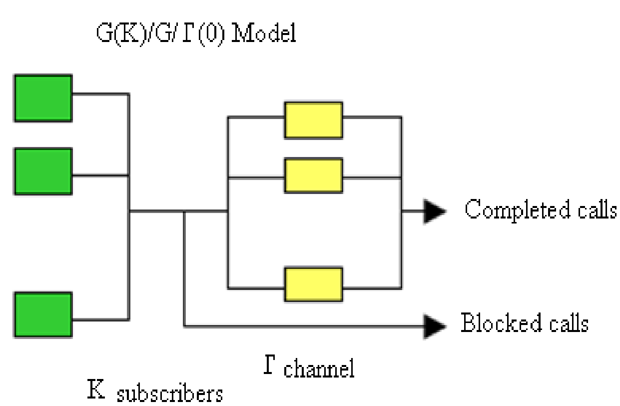

Fig.2. WRN model with K subscriber; Γ available wavelength

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Average number of circuit carried by network E (N) is given by

$$E[N] = \frac{Kr \sum_{n=0}^{\tau-1} \binom{K-1}{n} r^n}{\sum_{i=0}^{\tau} \binom{K}{i} r^i}$$

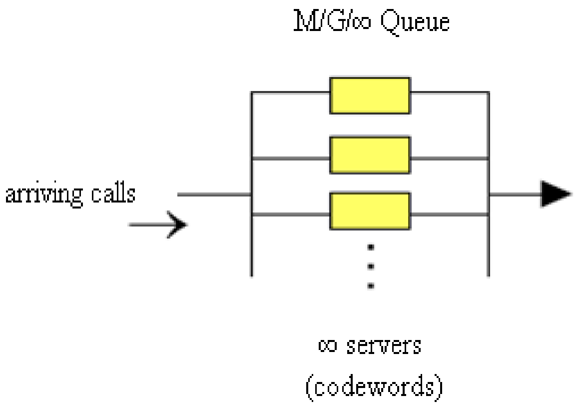

Fig.3. OCDMA Model with k subscriber and ∞ number of channel

In OCDMA model we assume that cardinality of spreading code is greater than the number of subscriber so that there is always a code word available. The probability of connected circuit is given by

$$P[N = n] = \binom{K}{n} r^n (1 + r)^{-K}$$

Therefore there will not be any blocking and the performance is limited by multiple access interference. When bit error rate increases up to maximum threshold or the data can not recovered exactly than outage occurs. The probability of outage is given by

$$P_{outage} = P\left[\sum_{i=0}^{N} V_i.\varepsilon_i > \tau\right]$$

$$P_{outage} = \sum_{m=\tau+1}^{K} \binom{K}{m} (pr)^m (1 + (1 - p)r)^{K-m}$$

The aggregate carried circuit load

$$E[N] = K\frac{r}{1 + r}$$

In WRN blocking probability depends upon the number of connected circuits while in OCDMA doping probability is zero, outage probability depend upon the number of active circuits. If it is more important to connect new circuits rather than the service quality ($P_{outage} > P_{block}$) than the traffic capacity of OCDMA is higher than the WRN. If more importance is given to the service quality ($P_{outage} > P_{block}$) than WRN is better than OCDMA.

III. PROPOSED WORK

Average circuit activity is an important parameter in designing of OCDMA call admission protocol. Up to now we have assume that circuit activity is constant value for all subscribers. As given in [9-10] for a traditional voice traffic, data network circuit activity is varied with time. So it is more important to take p as a random variable with some known probability distribution f(p).then the distribution for active circuit is

$$P[M = m] = \int_0^1 P[M = m/p] f(p) dp$$

Where $P[M = m/p]$ is same as in traditional OCDMA.

From the Bayesian distribution [11] that is if p have some known probability distribution than measure s N and M at time t to calculate P_{outage} at time t+Є, the posterior distribution f(p | N = n, M = m) can be used instead of f(p).

$$f(p|N = n, M = m) = \frac{f(p).P[M = m|N = n, p]}{\int_0^1 P[M = m|N = n, p].f(p)dp}$$

For a heterogeneous data network different subscribers have different values of p. suppose that it is known that the network consists of K_c "class c" subscribers that utilize their circuits with activity variable pc. In such a case, a class-based loss model may be used [12]. We illustrate the approach for an OCDMA network. If C is the set of subscriber classes, we define vectors p = (p_c; c Є C), N = (N_c; c Є C), and M = (M_c; c Є C) for activity, connected circuits, and active circuits, respectively.

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$$P[N = n] = \prod_{c \in C} \binom{K_c}{n_c} r^{n_c} (1 + r)^{-K_c}$$

Using this we find that

$$P[M = m/p] = \prod_{c \in C} \binom{K_c}{m_c} {\alpha_c}^{m_c} (1 + \alpha_c)^{-K_c}$$

where

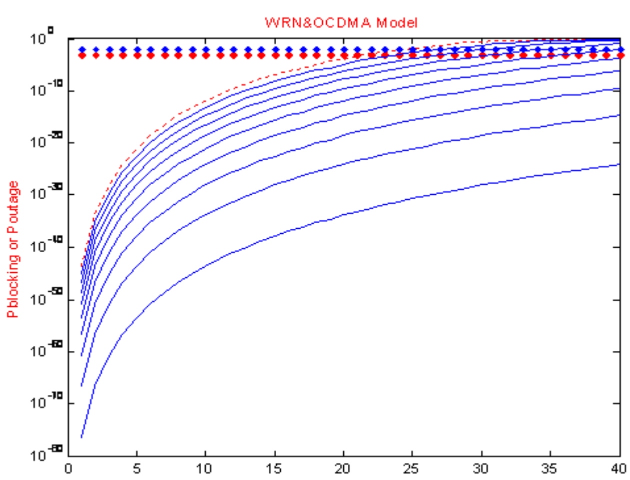
$$\alpha_c = \frac{p_c r}{(1 + (1 - p_c)r)}$$

And outage probability is given by

$$P_{outage} = \int_0^1 P\left[\sum_{c \epsilon C} M_c > \frac{\Gamma}{p}\right] f(p)dp$$

IV. SIMULATION RESULTS

For K= 48 subscribers and Γ= 32 channels, the operating constraint are $p_{outage}^{max} = 10^{-2}$ and $p_{blocking}^{max} = 10^{-3}$, the graph between aggregate carried circuit load and P_{outage} is given in Fig.4 with circuit activity ranging from 10% to 90% and traffic capacity Vs circuit activity p is given in Fig. 5. It is found that aggregate carried circuit load is greater in OCDMA.



For K= 64 subscribers and Γ= 32 channels, the operating constraint are $p_{outage}^{max} = 10^{-6}$ and $p_{blocking}^{max} = 10^{-2}$, the graph between aggregate carried circuit load and P_{outage} is given in Fig.6 with circuit activity ranging from 10% to 90% and traffic capacity Vs circuit activity p is given in Fig. 2(b). The operating constraint are $p_{outage}^{max} = 10^{-6}$ and $p_{blocking}^{max} = 10^{-2}$.

A heterogeneous data network has been taken with different subscribers having different circuit activity and a network with 64 subscribers having different circuit activity ranging from 10% to 90%, the operating constraint are $p_{outage}^{max} = 10^{-6}$ and $p_{blocking}^{max} = 10^{-2}$ has been taken.

Table I

Comparison of teletraffic capacity for different outage and blocking constraints

p_{outage}^{max}	$p_{blocking}^{max}$	OCDMA	WRN	Heterogeneous data network
10^{-2}	10^{-5}	31.2	16.2	33.5
10^{-2}	10^{-4}	31.2	18.0	33.5
10^{-2}	10^{-3}	31.2	20.4	33.5
10^{-2}	10^{-2}	31.2	23.6	33.5
10^{-3}	10^{-2}	27.4	23.6	29.3
10^{-4}	10^{-2}	24.5	23.6	27.4
10^{-5}	10^{-2}	22	23.6	26.2

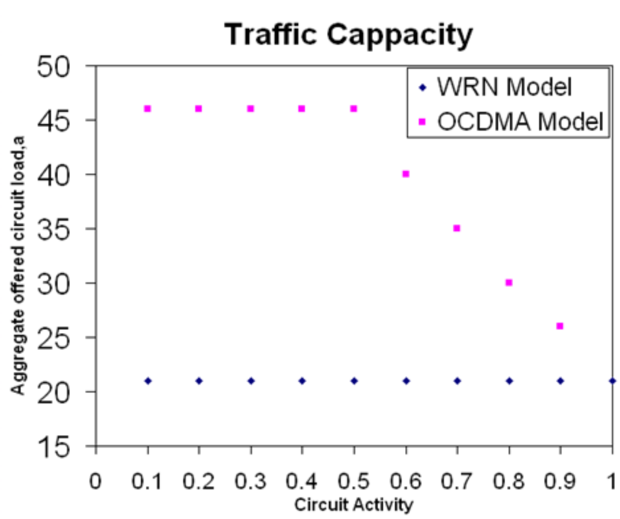


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Fig. 4. Plot for P_{outage} or P_{block} Vs aggregate offered circuit load with K = 48 subscribers, Γ= 32 channels p_{outage}^{max} = 10^{-2} and $p_{blocking}^{max}$ = 10^{-3}.

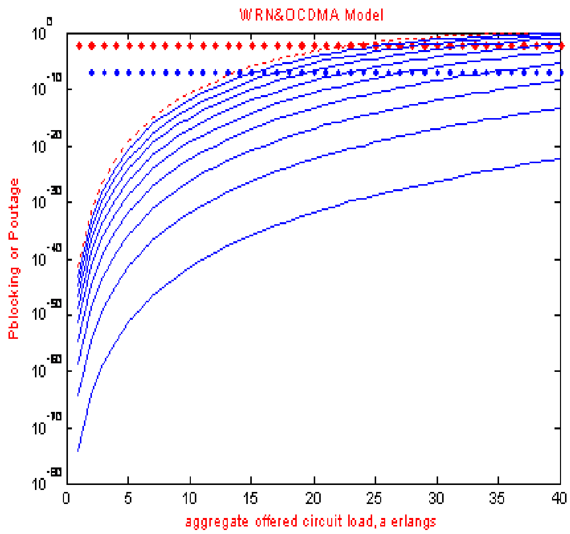

Fig. 6. Plot for P_{outage} or P_{block} Vs aggregate offered circuit load with K = 64 subscribers, Γ= 32 channels p_{outage}^{max} = 10^{-6} and $p_{blocking}^{max}$ = 10^{-2}.

V. CONCLUSION

A framework for understanding the statistical multiplexing properties and determining the teletraffic capacity of a circuit-switched OCDMA network carrying bursty data have been developed, where the cardinality of the CDMA spreading code is larger than the number of subscribers, each circuit is received with equal power, and performance is limited by MAI. In OCDMA, arriving circuit requests will always be accommodated by the network, while the BER of the other users on the network degrades gracefully. Thus, traditional blocking, which we modeled with the $G(K)/G/\Gamma(0)$ loss model for a circuit-switched WRN, is replaced by OCDMA with a $G(K)/G/\infty$ queuing model and an outage probability. An outage occurs when the number of actively transmitting circuits on an OCDMA network exceeds an outage threshold Γ such that all circuits experience an unacceptably degraded BER. This is defined the teletraffic capacity as the maximum aggregate carried circuit load that can be accommodated by the network such that constraints on outage and blocking probabilities are satisfied.

Comparison of an OCDMA network has been done with outage threshold Γ to a WRN with the same number of subscribers and Γ wavelengths (see Figs. 4 and Fig. 5). It is found that the teletraffic capacity of OCDMA exceeds that

Fig. 5. Aggregate offered circuit load Vs Circuit activity with K = 48 subscribers, Γ= 32 channels p_{outage}^{max} = 10^{-2} and $p_{blocking}^{max}$ = 10^{-3}.

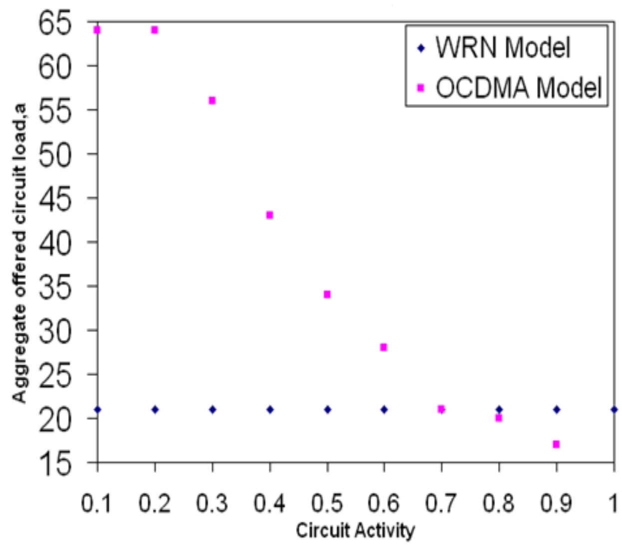

Fig. 7. Aggregate offered circuit load Vs Circuit activity with K = 64 subscribers, Γ= 32 channels p_{outage}^{max} = 10^{-6} and $p_{blocking}^{max}$ = 10^{-2}

of a WRN in all cases, except when circuit activity p is very high while the outage constraints p_{outage}^{max} are much more stringent than the blocking constraints $p_{blocking}^{max}$. Therefore, OCDMA is well suited to applications when conventional blocking is undesirable, and/or circuits carry bursty data. For example, for OCDMA and WRN with K = 64 subscribers, Γ = 32 with circuit activity p = 40% as in voice systems as shown in Fig. 6 and Fig.7, respectively, even when the constraint on outages is more stringent than the constraint on blocking (p_{outage}^{max} =10^{-6} , $p_{blocking}^{max}$ = 10^{-2}), the teletraffic capacity of OCDMA is about 37 connected circuits as compared to about 23 circuits for the WRN.

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