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State occupancy estimations for shared channel concept

Abstract

An analysis of state occupancy provides an insight into the spectral cost of the protocol options. This paper examines state occupancies of UEs utilizing a shared channel for typical IP data traffic. It recommends that a common signaling channel is employed for assigning resources of both the downlink and uplink shared channel.

1.0 Introduction

A shared channel concept has been proposed for the downlink and uplink channels that are better suited for bursty packet data traffic [1][2][3]. The shared channel allows UEs to transmit and receive data bursts at high rates lowering the overall delay by taking the greatest advantage of statistical multiplexing. The high rate bursts require the network tightly manage resources to insure that the appropriate OVSF codes are assigned on the downlink and the aggregate interference does not exceed the noise rise on the uplink. In both cases, the network must convey new assignments on a frame by frame basis. Fundamentally, there are two approaches for fast assignment of resources: either use one common control channel called the ACCH, or use multiple dedicated control channels.

The optimum control channel configuration can be implied from data traffic patterns. If a large population of UEs monitor the control channel simultaneously, a common channel will be superior, while if only a few UEs monitor the control channel, separate dedicated channels would be preferable. This paper presents state occupancy numbers, based on simulation results of World Wide Web (WWW) browsing traffic models [4] [5], showing that a common control channel will be more efficient, with respect to the power budget, for higher shared channel utilization. The limitation of the WWW traffic models is discussed, while measured results show that packet calls may tend to be longer than expected. As a result, the analysis suggests the number of simultaneous users will increase, favoring the common control channel approach.

As a result of the analysis, it is recommended that the 3GPP adopt both the common and dedicated control channels for standardization. Furthermore, it is recommended that both signaling options be mandatory for the shared channel capable UEs and optional in the UTRAN.

2.0 Background

In both ETSI and TIA, data traffic has been modeled using a packet train with varying statistics based on the type of transfer as described in [4][5]. Figure 1, reproduced from [4], illustrates a typical packet data session. The focus of this analysis will be for Web browsing, however, it may be applied to FTP and email transfer as well. The traffic is modeled as distinct sessions with a Possion arrival process. Each session marks a period of higher activity comprised of a number of packet calls. The number of packet calls per session is geometrically distributed while the time between packet calls is exponentially distributed. If the session models a Web browsing session, then the packet call models a Web page download and intermediate time models the think time used peruse the Web page. Each packet call consists of one or more packets whose inter-arrival time and length are both exponentially distributed. The packet interarrival time selected by ETSI for Web browsing is proportional to the link data-rate. In fact, the packet interarrival rate is selected such that the packet call represents a nearly continuous transfer. This last fact is useful to derive some analytical results.

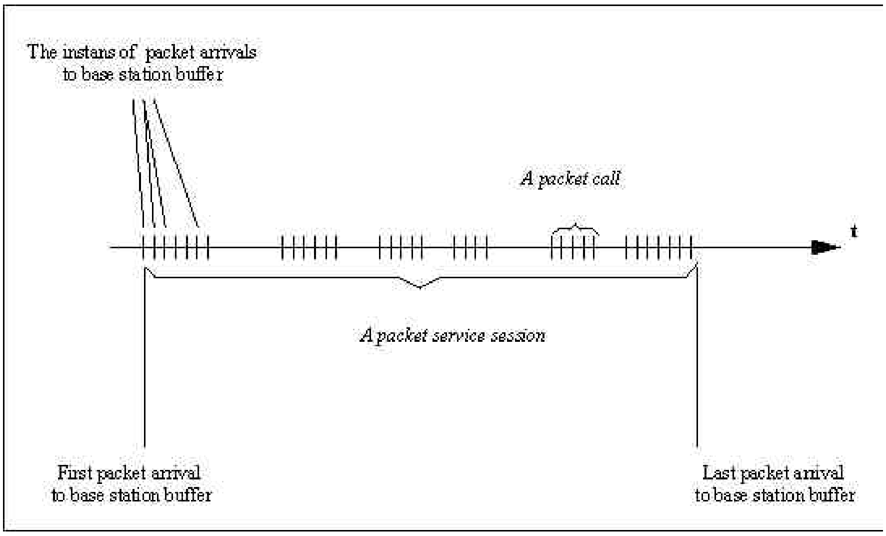

Figure 1 Illustration of a WWW browsing session.

3.0 Analytic Results

To approximate the number of simultaneous data calls, the shared channel may be modeled based on a M/M/1 queue. If each packet call is viewed as the arrival event, queuing theory predicts the number of simultaneous packet calls, N, based on the utilization of the link [6] as:

$$N = \frac{\rho^2}{(1-\rho)}$$

where

ρ = utilization of the link.

For this analysis, the utilization of the channel describes the percentage of time the data pipe is full. For example, a 384 kbps shared channel utilized at 75% would transfer on average 288 kbps per second. In physical terms, the utilization specifies the packet session arrival rate. For a given utilization, the packet session arrival rate can be calculated based on the data traffic model's transfer size per session. This calculation is performed for the simulation in the next session. Figure 2 shows a plot of the analytical results.

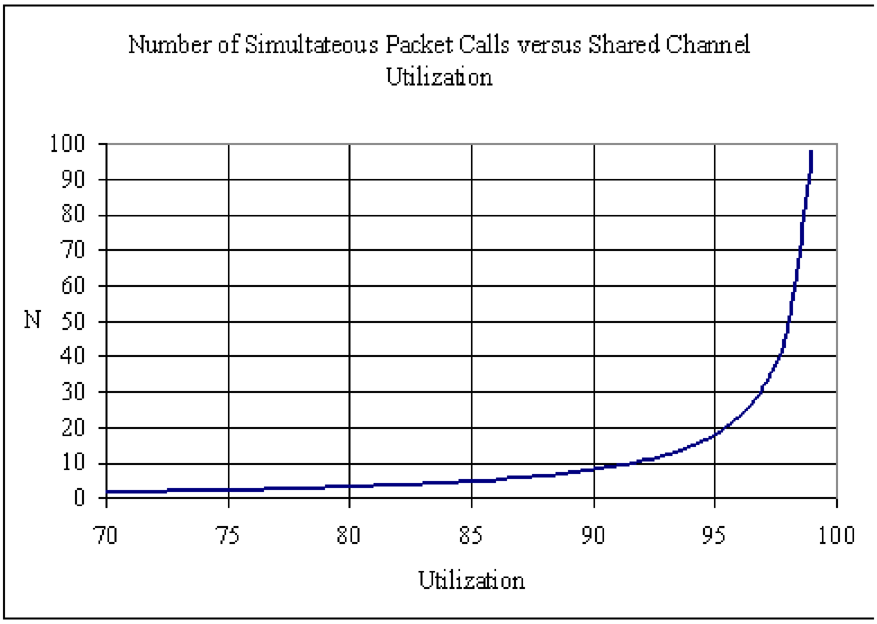

Figure 2 Analytic estimate of the average number of simultaneous packet calls.

From the diagram it is clear that as the utilization of the shared channel increases the number of calls increases dramatically. As a benchmark, it is estimated that the system resources consumed by one common control channel are equivalent to the power amplifier (PA) resources consumed by 10 dedicated channels. Therefore the results suggest that the ACCH will be more efficient when resources are most needed, such as at link utilizations above 90%.

4.0 Simulation Results

As a comparison, the packet data simulation that was used early to present the benefits of a "fat-pipe" scheduling [2] has been modified to monitor the number of simultaneous packet calls. For this investigation, the simulation models the scheduling of multiple users on a 384 Kbps shared channel. The model parameters are identical to those presented in [2]. The simulations runs were conducted for 75%, 90%, 92%, and 95% shared channel utilizations based on a session arrival rate of 0.60, 0.70, 0.72, and 0.76 per second, respectively. Figure 3 presents the cumulative probability of N or more simultaneous packet calls. Table 1 tabulates the mean and other statistics for the simulation runs.

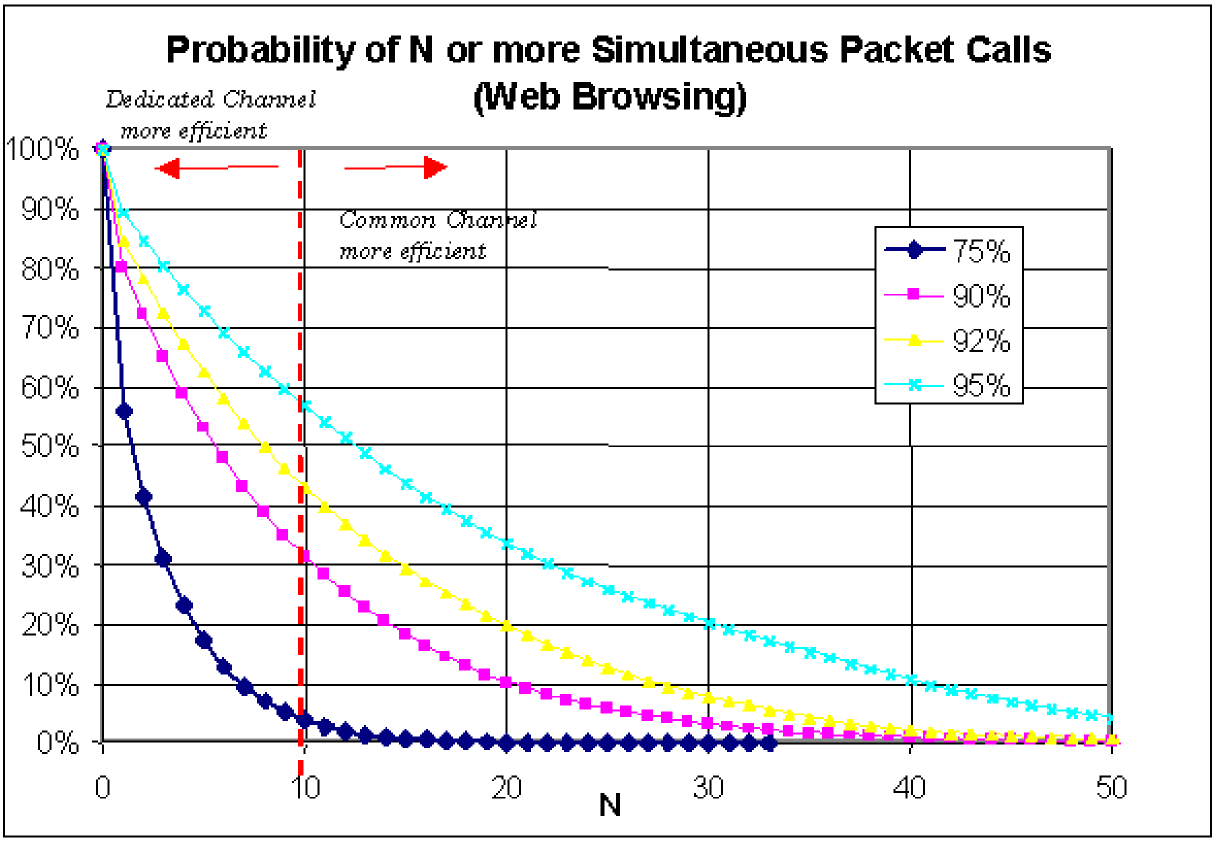

Figure 3 Probability of N or more simultaneous packet calls.

Table 1 Simulation Results for Various Shared Channel Utilizations

Shared Channel Utilization	Session Arrival Rate	Mean number of Simultaneous Users		Likelihood a Common Channel will be more Efficient	
		Analytic	Simulated	10:1	20:1
95%	0.76	18.05	16.5	57%	34%
92%	0.72	10.58	10.9	42%	20%
90%	0.70	8.1	7.86	31%	10%

70%	0.60	2.25	2.19	7%	0.3%

The simulations show good agreement with analytical results. As before, the simulation shows the dedicated control channels will be more efficient for low utilizations, however, the common channel will be more efficient when resources are needed the most. Assuming a 10:1 ratio of PA resources required to support one common channel versus one dedicated channel, the simulation shows that the common channel will be more efficient in terms of power budget when shared channel utilization is above 92%. Even if the estimated ratio for dedicated to common channels is as high as 20:1, a common channel will prove useful. The common control channel bounds the PA resources consumed by shared channel signaling bolstering the stability of the shared channel during periods of peek loading.

5.0 Limitations of data models

The data traffic models used by ETSI and TIA have limitations that may underestimate the duration of packet call. First, the models are based on packet trains. In general, packet trains perform well when trying to reproduce aggregate traffic statistics. They will faithfully model the self-similar nature of data traffic. However, packet trains do not model the interaction with the transport layer and the radio link very well. The transport layer performs link rate adaptation and congestion control that interacts with the underlying radio link protocols. These interactions may effectively prolong the packet call. Secondly, the models suggest that packets are nearly consecutive within a packet call. However, measured traces of Internet traffic suggest otherwise. For example, Figure 4 depicts the trace of a Web transfer captured over a 1B ISDN connection. The packet size for uplink and downlink transfers are plotted versus time. The user was reading the Wall Street Journal Interactive edition for 8 minutes. (The Wall Street Journal Interactive edition is a popular version of a popular U.S. financial paper.) The packet calls tended to last 10 percent longer that the data transfer size suggested. The analysis of the Web browsing tracing and implications will be discussed.

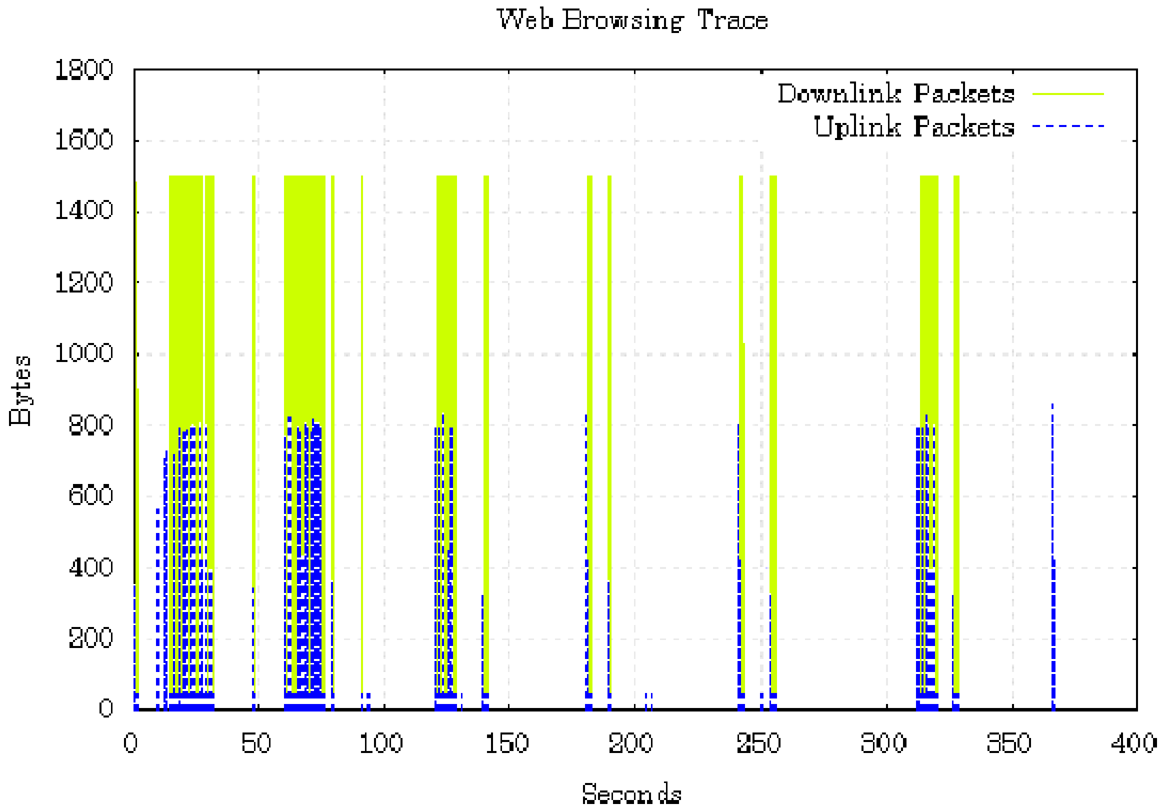

Figure 4 Web trace captured over dedicated 1B ISDN connection.

Without a priori knowledge on the duration of the packet call, it is necessary employ a heuristic for establishing when a dedicated channel will active. For this analysis, a dedicated channel was initiated every time a data packet exceeded 200 bytes. Packets smaller than this were assumed to be carried on the RACH or FACH. After each packet transmission, the dedicated channel was held for period of inactivity equal to 2 times the typical packet transfer time before dropping in order to include successive packets. The hold time was reset on the arrival of each new packet. The Web browsing session in Figure 4 had a total of 19 individual packet calls with a average transfer size of 25 Kbytes with an average duration of 3.5 seconds. The longest call contained 290 individual packets while the shortest called contained only one. The average data rate for the session was only 11 kbps.

Figure 5 shows a close-up of one of the packet calls in the session. The dashed line shows when a dedicated control channel, in the form of a DPCCH, would be held and dropped. For the packet call shown, the DPCCH was held continuously. However, the average gap between the beginning and end of consecutive packets was non-zero. Therefore, the DPCCH was held about 10% longer than it would have if the data had been sent in one contiguous block.

Returning to the initial analytical results presented in Section Analytic Results, it is expected that the prolonged packet calls will effectively decrease the service rate of the system and shift the results of Figure 2 to the left increasing the number of queued UEs. By decreasing the service rate, this will effectively raise the utilization of the link by 10% for the same session arrival rate moving the breakpoint of the curve down from 92% to 84% and increasing the average number of concurrent packet calls.

The analysis has shown that the typical Web browsing session with average data rate of only 11 kbps differs significantly from the packet train models defined by ETSI and TIA. It suggests that the packet call duration will be longer then the models predict, increasing the number of concurrent packet calls. The common control channel fixes the resources required for signaling shared channel assignments and provides a worthwhile alternative to dedicated control channels. The control channel assures that packet will be well supported on the 3GPP system regardless of the specific user traffic patterns.

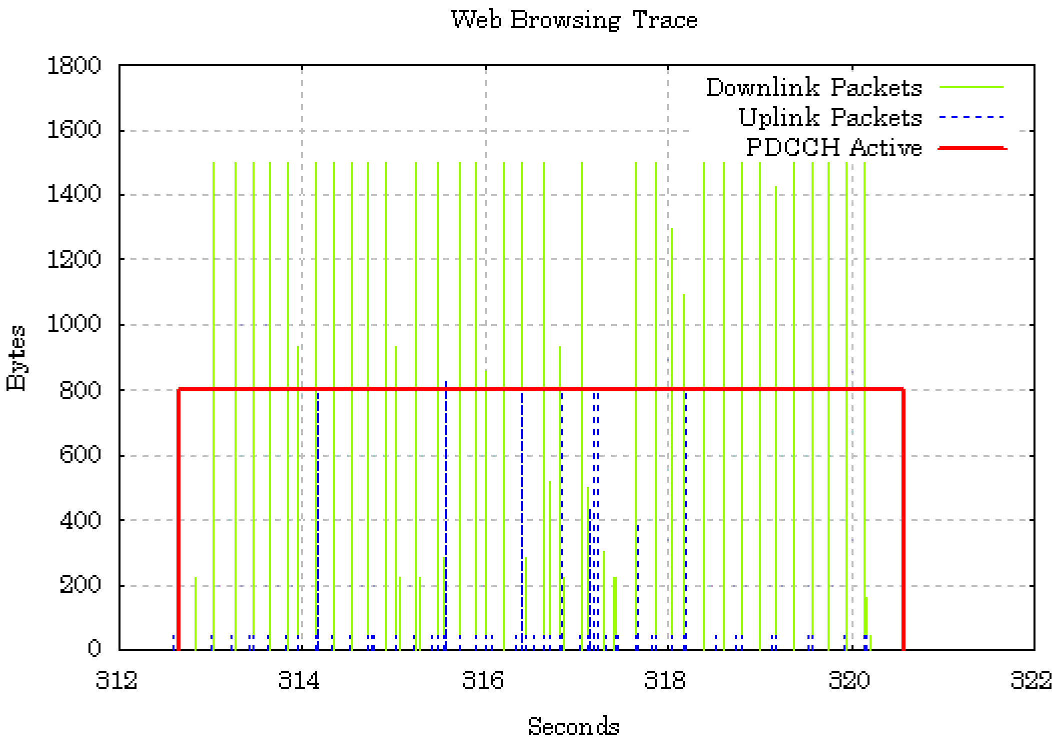

Figure 5 Close-up of one packet call within the Web trace.

6.0 Conclusion

The optimum control channel configuration has been investigated with respect to data traffic patterns. State occupancy numbers based on analytic and simulation results of WWW browsing traffic models were presented showing that a common control channel will be more efficient for higher shared channel utilization. The limitation of the WWW traffic models discussed and the measured results presented suggest that packet calls tend to be longer than expected. As a result, the analysis concludes the number of simultaneous users will increase favoring the common control channel approach.

It is recommended that the 3GPP adopt both the common and dedicated control channels for standardization. Furthermore, it is recommended that both signaling options be mandatory for the shared channel capable UEs and optional in the UTRAN.

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[2] Motorola, "Channel Bandwidth Allocation Strategy", SMG2 UMTS L1 682/98

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[6] Bertsekas and Gallagher, "Data Networks 2nd Edition", Prentice Hall, Englewood Cliffs, New Jersey 1992