

A Complexity Cost function for a network of WCDMA Basestations using Software Defined Radio with Multi-User Detection.

Paul Burns and Mark Reed
National ICT Australia
Australian National University
Canberra 0200
ACT, Australia

paulburns@simplexity.com.au

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Abstract - This paper determines a cost function for a network of WCDMA-FDD Base Stations (Node-B's) for the purpose of dimensioning a Software Defined Radio (SDR) implementation. This cost function allows for both a conventional direct-sequence spread spectrum receiver and one that uses a Multi-User Detector (MUD). An SDR architecture is proposed and the cost function is expressed in terms of cell diameter and signal processing load. The cost function is developed in terms of a large number of system parameters including the cost of using spectrum. Based on certain assumptions and by implementing a more advanced MUD-receiver it is shown that the network cost can be reduced when cell size must be maintained above a minimum figure i.e. base station sites are limited.

I. SUMMARY

Currently the signal processing intensive parts of the physical layer in most WCDMA BTS's (and Ue's) are implemented by fixed function application specific integrated circuits (ASIC's) that have been designed for the worst-case cell dimensions and user-density. This worst-case allows a small set of ASIC devices to meet the Layer 1 signal processing requirements for all classes of BTS.

The literature includes many references for the capacity and dimensioning of CDMA air-interfaces (including [3],[9],[5] and [6]), these all assume that the BTS signal processing is dimensioned for the worst case cell dimensions and user-density and they do not consider the cost due to complexity for an SDR implementation. Procedures are developed in [7] & [8] that minimizes the cost of a mobile network however these do not consider a software radio implementation for the basestations. A software radio architecture using multi-user detection is considered in [9] however this does not consider the network aspects.

The theoretical SDR requirements for WCDMA are estimated in [2] where it is recognized that the signal processing power of a CDMA system increases with both number of users and larger cell size. This reference also does not consider the cost due to complexity.

A cost function [1] for a network of SDR BTS's has been developed by Burns and Reed, however this assumes a spectrum limit of 20 MHz, does not consider

the use of MUD and does not consider the cost of consuming spectrum.

Therefore this paper sets about to determine a new cost function for a network of WCDMA BTS's implemented using Software Defined Radio (SDR) where the basestation receiver can be implemented using either a conventional detector or as one using a multi-user detector. The cost function is not spectrum limited and also considers the cost of consuming spectrum, this provides a more realistic BTS and network planning tool. The paper shows that:

- the cost function has a minimum and corresponding optimum cell size
- and by using MUD,
- larger cell size is possible with limited spectrum and
- lower cost is possible when cell size must be maintained above a minimum figure.

II. NETWORK LEVEL ANALYSIS

Consider a portion of a WCDMA cellular network with area A_p where each sector covers the same area and is perfectly hexagonal. Let us assume that the area uses 120 degree cell sectorization (i.e. 3 sectors per BTS) where the BTS's are placed in the corner of a hexagon with diameter D .

Assuming that A_p contains a uniform density of users λ where each user generates T_k erlangs of traffic during the busiest hour, each BTS in A_p will be required to support a maximum of T_{BTS} erlangs of traffic.

The relationship [1] between traffic and sector diameter is then

$$T_{BTS} = 3(\lambda T_k) \sqrt{3} D^2 / 2 \quad (1)$$

Assume that spectrum is purchased in blocks of 5 MHz (paired for FDD) for the entire area of the network at a cost of C_F per block. Let N_c be the maximum number of 5 MHz carriers required for the network. If N_s is the number of subscribers, then the network must provide $N_s T_k$ traffic channels where the spectrum cost is $(C_F N_c) / (N_s T_k)$ per traffic channel. Let C_N' be the cost per unit area to populate A_p with basestations.

III. MUD RECEIVER

N_c is a function of the number of users that can be supported by the forward and reverse links and T_{BTS} . By using a MUD

receiver T_{BTS} can be increased by a factor of 3 for the same N_c .

IV. BTS SOFTWARE DEFINED RADIO ARCHITECTURE

Each BTS is implemented using the SDR architecture described in Figure 1. The DSP resources are programmable to implement conventional or MUD receivers.

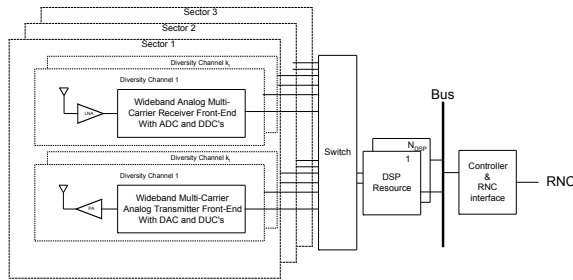


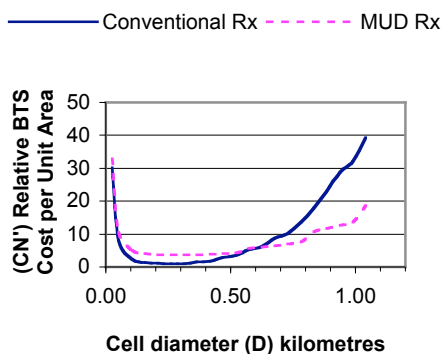
Fig 1 SDR BTS Architecture

If UL_{CR} [1] is the number of processing instructions required per second (MIPS) per traffic channel for a non-MUD rake receiver, then assume that the number of MIPS required for a MUD-receiver is 10 times larger.

V. NUMERICAL RESULTS

The relative cost function (compared with the minimum cost implementation) C_N' was evaluated (with and without MUD) using a set of system parameters and plotted for a traffic density of 1500 Erlang/km², see Figure 2. This illustrates that the minimum cost SDR WCDMA network is achieved by not limiting cell diameter and by using a conventional receiver, i.e. minimum occurs for a cell diameter of 0.26 km where N_c is one (i.e. 5 MHz of spectrum). However if cell diameter must be greater than 0.57 km, then network cost can be reduced by implementing BTS receivers with MUD, e.g. by using MUD for a cell diameter of 0.89 km the cost is halved when compared to implementing a conventional receiver.

Fig 2 Relative Cost Function for a traffic density of 1500 Erlang per km²



The use of MUD also increases spectrum efficiency e.g. N_c is reduced from 8 (40 MHz) to 3 (15 MHz) for a cell diameter of 0.89 km. If the network is spectrum limited to a value of $N_c=1$ then the cell diameter can almost be doubled from 0.31 km to 0.55 km by using MUD receivers in a network area required to support 1500 Erlang per km².

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