Ratnayake, Nisal Lahiru (2010) ***Modelling the broadband wireless channel in rural Australia***. In: IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM 2010), 14 - 17th June 2010, Hyatt Hotel in Montreal Downtown, Montreal, QC.

Modelling the broadband wireless channel in rural Australia

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I. Introduction

The internet infrastructure which supports high data rates has a major impact on the Australian economy and the world. However, in rural Australia, the provision of broadband services to an internet dispersed population over a large geographical area with low population densities remains both an economic and technical challenge [1]. Furthermore, the implementation of currently available technologies such as fibre-to-the-premise (FTTP), 3G, 4G and WiMAX seems to be impractical, considering the low population density that is distributed in a large area. Therefore, new paradigms and innovative telecommunication technologies need to be explored to overcome the challenges of providing faster and more reliable broadband internet services to internet dispersed rural areas. The research project implements an innovative Multi-User-Single-Antenna for MIMO (MUSA-MIMO) technology using the spectrum currently allocated to analogue TV. MUSA-MIMO technology can be considered as a special case of MIMO technology, which is beneficial when provisioning reliable and high-speed communication channels. Particularly, the abstract describes the development of a novel MUSA-MIMO channel model that takes into account temporal variations in the rural wireless environment. This can be considered as a novel approach tailor-made to rural Australia for provisioning efficient wireless broadband communications.

II. Knowledge Gap

Characterization of the MIMO channel is vital, to optimize the performance and adequate planning of wireless communication systems in different scenarios (indoor and outdoor) and operating frequencies [2]. Moreover, the effectiveness of MIMO communication technology depends on the availability of high quality channel state information (CSI) at the communicating nodes [3]. Usually, CSI is obtained by periodic transmission of known training data from which the receiver estimates the channel transfer matrix. When the channel state is highly varying, this training must be frequently repeated, using the available transmission bandwidth and therefore resulting in low effective channel capacities. These observations suggest that accurate MIMO performance prediction requires an accurate representation of channel temporal variations[3].

As shown by Spencer et al.[4] and Almers et al. [5], time-varying effects have not been taken into account in most of the MIMO channel models. Although several attempts [3], [6] have been made to incorporate time-varying effects in MIMO channel modelling, those models assume that temporal variations occur mainly because of receiver movement. Suzuki et al. [7] have shown that temporal variations such as those caused by changing weather conditions in outdoor environments have a significant effect on the received signal. Furthermore, it is important to accommodate these time-varying effects in the MIMO channel models in order to predict the accurate channel state information (CSI).

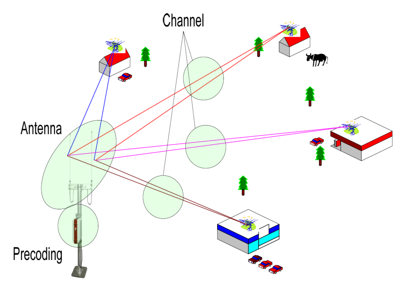

Figure 1. MUSA-MIMO Technology

III. Significance and Innovation

As it is the first time Multiple Users with Single Antenna for MIMO (MUSA-MIMO) technology of this kind has been developed, there are no other existing channel models that suit such technology and associate time-varying weather conditions that define the wireless channel in the Australian rural environment.

Therefore, this research will fill the above knowledge gaps by developing the first channel model for the tracking and prediction of CSI, to characterize the novel and newly developed MUSA-MIMO technology under different weather conditions. The final outcome will be innovative since this is the first MUSA-MIMO channel model that will be created parallel with the MUSA-MIMO system designing phase. Furthermore, for the first time, a MUSA-MIMO channel model will incorporate time-varying effects that occur due to varying weather conditions in the rural Australian environment.

IV. Methodology

The research methodology can be illustrated in three phases. The first phase conducts MUSA-MIMO channel simulations

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using the communications toolbox of MATLAB 7.8.0 (R2009) software. The second phase conducts an experimental study to measure the effect of varying weather conditions on rural MUSA-MIMO channels under realistic propagation conditions. The third phase will focus on an analytical study of the experimental data in order to characterize the rural MUSA-MIMO channels under different weather conditions, and to develop a channel model that can accommodate varying weather conditions.

Pathloss simulations (Figure 2) have been conducted as an initial step to develop the novel channel model. The distance from the transmitter to the receiver is taken as 20 km and the carrier frequency selected for the simulations was 600 MHz. Hata model (for rural environments) [8], IEEE 802.16 Type A and C models [9] have been implemented as benchmark models. These models will be incorporated in the 3GPP spatial channel model [10], which will be used to simulate the rural MUSA-MIMO channels.

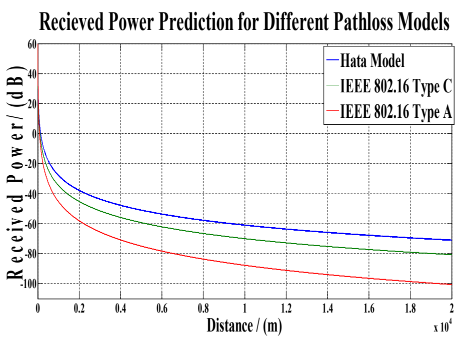

Figure 2. Pathloss Simulations

Then, channel measurements will be conducted for MUSA-MIMO system in different weather conditions. Rain and wind have been identified as the main contributors for time variations in rural environments (environments with vegetation) [11]. Therefore, measurements will be conducted under three rain intensities (RIs) and wind speeds (WS). The threshold values for RIs and WS are taken from the research conducted by Meng et al. [11]. Three RIs are introduced as slight rain (RI < 2mm/h), moderate rain (2 mm/h < RI < 10 mm/h) and heavy rain (RI > 10 mm/h). Similarly, wind is classified by the wind speed (WS) as light wind (WS < 20 km/h), windy (20 km/h < WS < 40 km/h) and strong wind (WS > 40 km/h).

The correlation between received signal strength (random variable) and relevant weather conditions (random variable with time) will be analysed. A relationship between the received signal and above weather conditions will be developed as done by Meng et al. [11]. As the final step, the variations obtained in different scenarios mentioned above will be incorporated with the current MIMO channel representation as a time-varying component. Therefore, the MU-MIMO system equation for the signal received by the k^{th} user can be extended as,

$$y_k = \beta_k H_k . x_k + n_k \qquad (1)$$

Where H_k, x_k and y_k is the propagation channel for k^{th} user, transmitted signal and received signal by the k^{th} user, respectively. β_k represents the time-varying component for user K, in time t. Furthermore, n_k represents the AWGN noise component experienced by the k^{th} user.

V. Conclusions

Two significant outcomes are expected from this research project. Firstly, the behaviour of rural MUSA-MIMO channels is investigated under different weather conditions. Secondly, as the theoretical outcome, this research will produce the world's first MUSA-MIMO channel model for the tracking and prediction of CSI under different weather conditions, as it is developed in parallel with the world's first MUSA-MIMO system (Technology) designing phase. A Matlab simulation and data collection campaigns are conducted to develop the novel channel model. Currently, the research progresses with Matlab simulations, to adopt 3GPP spatial channel model [10] to represent rural MUSA-MIMO channels.

VI. Acknoledgemets

I wish to thank my principal supervisor, Dr. Karla Ziri-Castro, for her contribution and excellent guidance to my PhD research project. Moreover, I wish to thank my associate supervisors, Dr. Hajme Suzuki and Dr. Dhammika Jayalath and my fellow researcher, Lakmali N. Atapattu for their contributions to this project.

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