Internet research 2017/18
Internet Research final report
Application IR170040 From Dr Haibo Zhang

Project Report

* indicates a required field

Research Title
Accurate synchronization for coherent joint transmission to provide better mobile Internet se rvice
This question is read only.

Please provide a short summary of the work that was completed as part of this project / research *
A comprehensive literature review has been undertaken. Existing solutions for centralized radio access network, coherent joint transmission, and time synchronization have been investigated and analyzed. A simulation platform has been developed. An algorithm for estimating delay and phase of an incoming signal has been designed and evaluated in simulations.
Describe the 'who, what, where, when and why' of your initiative

Timing

Is your project / research complete? *
◉ Yes ○ No
If your initiative is still in progress, pick 'no'

Start Date	**Finish Date**
11/05/2018	01/04/2019
Must be a date.	Must be a date.

Milestones

What have been the major steps / stages (i.e. milestones) involved in delivering your initiative to date?

Milestone	**Description**

Literature review	We found out that tight synchronization for APs that are not communicating over-the-air due to obstacles such as mountains or buildings has not been well investigated. This makes it challenging for coherent joint transmission since such kind of conditions are very common for hilly areas or dense city centers, especially in New Zealand. We have investigated existing solutions based on the “master and slaves” approach and analyzed the feasibility of existing solutions in achieving the accuracy required for coherent joint transmission.
Developing a simulation platform for distributed MIMO system	A comprehensive simulation platform has been developed. The platform is capable of modeling a given 3D multipath environment with a given number of MIMO APs and a 3D walking user that emulates realistic patterns of human movements. A detailed model of a smartphone was also developed in order to realistically simulate wireless signal propagation. During this research project, we found that the antenna orientation of the user equipment significantly influences the reception quality, which also can be taken into account in the tight synchronization of APs.
Conference paper preparation	Based on the results of the second milestone, we prepared a conference paper that has been accepted for presentation in IFIP Networking 2019 conference in Poland, Warsaw.

Developing algorithms for tight synchronization of cooperating APs for coherent transmission	Based on the knowledge gained from the development of the simulation platform and the preparation of the conference paper, we developed an algorithm that enables synchronization of two or more APs without the "Master and slaves" approach. The developed solution synchronizes APs based on the target user signals. Using signals from the user, APs separately estimate the position and orientation of the user equipment and send the estimations to the central server via C-RAN backhaul. Once results from cooperating APs become enough close to each other, the server commands the APs to estimate their relative phase shifts. It becomes possible because the APs can eliminate the phase shifts caused by distances between APs and the user equipment, and finally estimate relative phase shifts caused by independent work of local oscillators of the APs.
Evaluating of the developed algorithm	Evaluation of the algorithm revealed that there is no strict need in the estimation of the user's antenna orientation. An accurate estimation of the target user's position becomes enough for phase alignment of cooperating APs.
e.g. planning; major activities; evaluation	

Outcomes

What outcomes were generated as a result of this project / research?

Outcomes are the changes that have occurred for the beneficiaries of your initiative. Generally outcomes can be framed as an increase or decrease in one or more of the following:

- Skills, knowledge, confidence, aspiration, motivation, (these are generally **immediate** or short-term outcomes)
- Actions, behaviour, change in policy (these are generally **intermediate** or medium-term outcomes)
- Social, financial, environmental, physical conditions (these are generally **long-term** outcomes)

Immediate outcomes occur directly following an activity (e.g. within 1 month); intermediate outcomes are those that fall between the immediate and long-term (e.g. between 1 month and 2 years); and long-term outcomes are those we expect to see years later (e.g. 2, 5, 10 or 50 years after the activity).

We also want to learn more about how you tracked the outcomes of your initiative - what you measured and how.

If you need more help understanding what outcomes are, read the help sheets at www.ourcommunity.com.au/evaluation

List your initiative's outcomes and attached information in the following table. Leave blank any fields that do not apply to your project.

Outcome	Were these outcomes anticipated?	Timeframe	Indicator	Verification Method
Comprehensive 3D channel simulation platform	Anticipated	Immediate		simulations
Conference paper	Unanticipated	Immediate		
Synchronization algorithm for non-communicating access points	Anticipated	Immediate		simulations
Knowledge, experience	Anticipated	Immediate		
Algorithm for reconstructing antenna orientation	Unanticipated	Long-term	The conference paper with the description of the algorithm has been accepted for publication	4 international reviewers assessed the novelty of the algorithm as good or very good
Outcomes are the changes that you believe were generated or influenced by your initiative. See information above.	Choose from the list	Choose from the list (see description above)	What you used to measure this outcome - e.g. 'change in teenage pregnancy rates from x to y'	e.g. survey; interviews; focus groups

What (if anything) did you change in your approach and practices as your project? research proceeded, and why? *

As it was proposed, we aim to develop a two-stage synchronization scheme, in which the first stage synchronizes all AP's clocks through the C-RAN backhaul and the second stage synchronizes the served user equipment with the serving APs. Through the literature review, we found that it is very challenging and even infeasible to achieve tens of nanoseconds accuracy in the first stage due to the uncertainties caused by task scheduling at the server side and other issues related to the backhaul communication. Fortunately, we found that it is possible to perform synchronization directly through the second stage driven by the target user instead of the C-RAN. Hence, we decided to develop a new "masterless" approach that can synchronize APs using signals from a target user. We focus on more actual problems in wireless communication such as realistic 3D channel modeling and phase synchronization in distributed MIMO APs without the "master and slaves" approach.

We may use this information to help inform others undertaking similar work

What did you learn as a result of undertaking this project/program? *

We have gained a deeper understanding of wireless signals propagation physics, and obtained experience in modeling 3D geometry-based channels for distributed MIMO systems.

The main take from this project is that we realized and witnessed on our experience that external research grants accelerate the development of science. Our 3D channel simulation platform confirmed the necessity and importance of consideration of communicating antennae orientations. This is the first model, in the best of our knowledge, that can dynamically model an arbitrary orientation of antennas. We hope that the published paper will shape the future of early stage validation methodologies for high-throughput communication.

We are particularly interested in lessons that may help others undertaking similar work. Think about what you learned about your inputs (money, skills, personnel, time - too much; too little; about right?); your assumptions (were they 100% right, only partly right, or were the results a complete surprise?); and the context of the project/program (timing; targeted beneficiaries; geographic settings - were they right; wrong; about right?)

How will you share your learnings from this project/research? *

We aim to publish further research outcomes in top-tier international journals and conferences.

The research outcomes and experience obtained from this project will also be used as an experimental concentration for innovative curriculum design of the Telecommunications Programme at Otago University (http://www.telecom.otago.ac.nz). We will design lectures based on these research outcomes for COSC402 - the advanced computer network paper offered at the Computer Science department of Otago University.

What mediums were used to share the learnings? Have you reached the audience you expected?

We'd love to see some visual and audio representations of your work. Please share below.

Upload files:

Filename: Paper_3_camera_ready_final.pdf
File size: 1.0 MB

Filename: Phase_Synchronization.pptx
File size: 186.2 kB

and/or

Provide web link:

Must be a URL

and/or

Provide additional details:

Please include captions, if relevant

Can we use your media content in our own communications?

◉ Yes ○ No ○ Please contact us first
e.g. in our annual report

Financial Report

* indicates a required field

Project Income & Expenditure

Please provide details of any project income (funds received) and project expenditure (funds spent) to date.

Use the 'Notes' column to provide any additional information you think we should be aware of.

Income Description	Income Type	Confirmed Funding?	Income Amount ($)	Notes
InternetNZ research grant	Other Income *	Confirmed *	$25,000.00	The community research grant received from InternetNZ

Expenditure Description	Expenditure Type	Expenditure Amount ($)	Notes
Experimental Hardware	Infrastructure and/or Hardware *	$3,461.00	Purchase USRP for experiments
Conference Registration Fee	Other Expenditure	$1,085.00	
Salary	Salaries and Wages	$10,043.00	Salary for research assistants
Overhead	Overheads	$8,978.00	

Income and Expenditure Totals

Total Income Amount	Total Expenditure Amount	Income - Expenditure
$25,000.00 This number/amount is calculated.	$23,567.00 This number/amount is calculated.	$1,433.00 This number/amount is calculated.

Have you experienced any issues with your intended project budget to date? If so, please explain reasons for any major variances or for providing incomplete information:

There is an underspend of $1433 due to the following two issues: (1) the hardware was purchased with a discount as it is used for research purpose; (2) one research assistant started a little bit late due to the work visa problem.

I am planning to write another conference paper based on the research outcomes, and would like to use the underspent money to cover the conference registration fee.

Certification and Feedback

Feedback

You are now nearing the end of this form. Before you review your application and click the **SUBMIT** button please take a few moments to provide some feedback. (If you would rather provide anonymous feedback, please go to **{{ Grantmakers: provide a link to an anonymous survey or delete this sentence }}**

Please indicate how you found the acquittal process:
○ Very easy ○ Easy ◉ Neutral ○ Difficult ○ Very Difficult

How many minutes in total did it take you to complete this form?
300
Estimate in minutes (i.e. 1 hour = 60 minutes)

Please provide us with your suggestions about any improvements and/or additions to this form that you think we need to consider:
it was convenient for us to follow the form.