Grants Round
2020 Grant Round Final Report
Application GR000262019/20 From Dr WANQING TU
Form Submitted 6 Sep 2021, 4:42pm NZST

Instructions

Kia ora. The questions below are to help InternetNZ understand the triumphs and challenges you have faced to date in your mahi we have supported.

We want to celebrate your successes and understand the obstacles you have encountered so far. This will help us all to learn what we could do differently next time.

This form will be placed on our website for transparency.

Please complete and submit this form no later than the date stipulated in your funding agreement. Should you be unable to meet the deadline, contact us to arrange an alternative date, by emailing funding@internetnz.net.nz. You may not be eligible to apply for further grants from InternetNZ if this is not submitted. The completion of this form should be overseen by someone with an intimate knowledge of the funded mahi.

Final project report

*** indicates a required field**

For your convenience, you will find some information for this section has prepopulated from previous forms you have completed.

Please amend any details as needed to ensure we have the most accurate information.

Project title *
UAV-aided Wireless Mesh Networking for Remote NZ Communities

Provide a short summary of the work that was completed as part of this project / research. *
The project team first investigated the optimal allocation of WMN gateways or routers so that the number of required WMN gateways or routers can be minimised while keeping all end users covered. We found that a hierarchical architecture presents a heuristic solution. Accordingly, a two-tier architecture is designed with the target of supporting several Gbps data rates.

We then studied UAV characteristics in terms of providing reliability in supporting ground-air connections. Simulations and experiments have been conducted. Based on these, we designed algorithms to efficiently handle UAV movements so that energy-efficient and perf ormance-guaranteed ground-aid links can be formed. Furthermore, we compared two major routing algorithms for the purpose of delivering high-performance data in our network.

In addition, we explored how to schedule flows so that our network is able to implement energy- and performance-aware transmission adjustments in a self-healing and self-organising way. Our study showed that Network Calculus is a promising tool to develop a simple yet effective scheduling policy for our communication purposes.
Describe the "who, what, where and when" of your initiative.

Is your mahi for this project complete? *
◉ Yes ○ No
If your initiative is still in progress, pick "no"

Start Date

01/05/2020

Must be a date.

Finish Date

06/09/2021

Must be a date.

When do you anticipate that your project / research will be completed?

06/09/2021

Must be a date.

Leave blank if this is an ongoing initiative or if finish date is unknown.

Are there any areas where you need further support to complete this mahi?

What are the outcomes of this project? *

• Algorithms and experimental/simulation results.

We designed a two-tier WMN algorithm to form a network architecture. At the lower tier, WMN gateways are guided to connect to as many end users as possible based on their coverage, the distribution density at different areas, end users' locations, and end users' service requirements. At the higher tier, connections between WMN gateways are established to form fast transmission paths.

Another major algorithm that we designed is the UAV trajectory adjustment algorithm. The algorithm enables UAVs to set up energy-efficient yet latency-controlled paths to transit their locations, without affecting the performance of other ongoing transmissions in the network.

A novel flow scheduling algorithm has also been investigated. By Network Calculus and exploiting the scheduling opportunities potentially provided by performance gaps, the algorithm enables UAVs, WMN gateways, and end users to dynamically share transmissions between them. When any devices fail or are interrupted (say because of depleted batteries), the algorithm helps to recover performance-guaranteed transmissions.

These major algorithms were developed partially based on our results from computer simulations as well as some onsite experiments.

• Software programs.

We have developed C++ code to implement most of our algorithms. This code can be used in NS2 or NS3 simulators. Our simulations for major routing algorithms can be a benchmark for further developments.

• Trained researchers.

Apart from the PI, two RAs and a research student have participated in the research and experiments. They have progressed greatly in developing research methods and experimental skills for networking research. They have also read a large number of articles and books to develop expertise for the work that they carried out for this project.

• Research dissemination.

Some of our results have been published in IEEE CCNC 2021. Other results are currently under revision or review by international journals. Our source code for experiments and simulations are published on GitHub. We have also presented some of our study results to international audience via a conference or online seminars.

Describe major achievements or outcomes of the project in terms of benefits for participants and/or others.

Who have you worked with to make this project happen?
The PI worked with two research assistants and one research student to conduct the planned research studies. The project also received great support from the Universities in order to smoothly administrate this project team.
For example, staff, volunteers, other organisations or support that has been instrumental in this mahi.

Describe any changes from the original proposal and the reason the changes were required.
We don't think that we have changed our research objectives from the original proposal.
We may use this information to help inform others undertaking similar work.

What did you or your team/organisation learn as a result of doing this project? *
• Ground architecture

A hierarchical architecture will be effective in providing resource-efficient coverage via ground WMN devices. In the communication scenarios of this project, the requirements for networking connections can be different in different areas as population distributions and connection properties are different. A hierarchical architecture helps to plan efficient ground connections based on individual areas' local needs and then strategically link different areas together in an efficient manner.

It would be good to take the unbalanced connection requirements into account when designing such a hierarchical architecture. Algorithms designed by us that employ multiple transmission rates, multiple channels, etc. can be enhanced to accommodate the unbalanced connection requirements.

• UAV connections

The quality of UAV connections relies on several factors including UAVs' energy levels, UAVs' mobility, UAVs' locations, etc. The relations between these factors and the performance of UAV connections were investigated via experiments and computer simulations. We learned that the dynamic adaptation of transmission modes based on the status of these factors could be useful for guaranteeing seamless connections under different network and UAV conditions. Thereby, we investigated multicasting routing in aerial networks to support group applications. We studied a seamless and efficient transition algorithm for aerial group communications which can be used to support ground group communications. Our theoretical and experimental studies have reported that the proposed algorithm is able to maintain high-performance data multicasting while enabling fast yet seamless transits for UAVs.

• Efficient data delivery

We looked into two major routing strategies by implementing computer simulations and found that they presented different characteristics in our UAV-aide WMN. In general, distance-vector routing protocols may process data routing quickly for applications with static ground devices, while link-state routing protocols can react to mobile applications on the ground better. Similar insights apply to the two types of routing protocols when they deal with dynamicity due to various causes such as link failure, energy consumption, or overloaded capacity, etc.

• Reliability

UAV energy constraints may degrade the reliability of the proposed WMN. Our computer simulations show that many existing mobility schemes cost energy and bandwidth to issue control overheads. As drones are low-cost communication devices, a simple yet effective way is to use further UAVs to replace UAVs with low energy levels. Namely, given the limited energy supply and the fast energy consumption during movement, a drone that has already served as a sender/forwarder may be unable to complete its mobile missions with its remaining energy. We nominate the new drone to move in the sender/forwarder's stead, enabling UAV transition activities while maintaining a reliable WMN architecture. This requires knowledge of instantaneous UAVs' energy levels. Alternatively, fixed power supply technology has been developed for UAVs which enables UAVs to be continuously charged via a cable connecting to a ground charging device. The use of this technology will also keep UAVs stable in windy weather. However, it limits the mobility of UAVs. A mixed use of both suggestions may provide a flexible solution.

Describe some areas for improvement and/or reasons for success and/or challenges. How will the things you learnt inform future projects?

How will you share the outcomes and lessons from this mahi? *

As mentioned, we have published some results and have been working on revising other results for potential publications. Most of our source code has been published on GitHub. We will also present the studies to an international audience through conferences and invited speakers.

To share the outcomes with end users or ISPs, we plan to visit local telecommunication companies and remote residences. The PI already contacted and discussed with a few local telecommunication providers and tried to call a remote community. Also, Twitter and LinkedIn have been used to promote this project.

What channels/mediums were used?

Which population group/s were affected by this project or program? *

Living environment > Rural/regional dwellers

Please choose only the group/s that were at the very core of this project/program.

Did you reach the audience you intended? *

We talked to local companies through University events or research offices. We were able to meet some end users during events (e.g., InternetNZ's gathering). The project has been introduced to postgraduate students in a postgraduate course on computer networks. Some study results were presented in an international conference.

Reflect on who you set out to help, and whether this changed at all through the course of the project.

What has the feedback been to date? *

In general, companies are interested in the project. Many existing developments use fibre-optics. But UAVs were already used to provide connectivity particularly when emergencies caused existing network infrastructure to fail. With the further maturing of UAV communication technologies, they seem to welcome the extended use of UAVs in existing computer network systems. On the other hand, a few companies are interested in different wireless mesh networking technologies to deliver data (say video) within a community area.

Consider whether you have permission before quoting any specific piece of feedback.

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

Upload files:

Filename: A_Seamless_and_Efficient_Transition_Algorithm_For_Aerial_Drone_Multicasting.pdf
File size: 253.9 kB

Filename: ComputerSimulationCode.zip
File size: 2.1 MB

Filename: SomeOnsiteExperimentResults.xlsx
File size: 16.5 kB

and/or

Provide web link: https://github.com/deuterium546/droneProject
Must be a URL

and/or

Provide additional details: https://github.com/W-Tu/UAV_Project
Please include captions, if relevant

Can we use your media content in our communications? *

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

Financial report

* indicates a required field

Project income and 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 grants	Other income	Confirmed *	$30,000.00	

Expenditure description	Expenditure type	Expenditure amount ($)	Notes
RA Wage.	Salaries and wages	$12,000.00	For two RAs.
DJI MAVIC Air 2.	Infrastructure and/or hardware	$3,398.00	For two.

Research Student Wage.	Salaries and wages	$6,000.00	For one part-time research student.
Wireless Routers.	Infrastructure and/or hardware	$579.96	For four.
Travel etc. for Survey & Onsite Experiments.	Evaluation	$1,000.00	
Administrative and Support.	Administrative and infrastructure	$7,022.04	Including the time for PI and other university supporting staff.

Income and Expenditure Totals

Total income amount
$30,000.00
This number/amount is calculated.

Total expenditure amount
$30,000.00
This number/amount is calculated.

Income - expenditure
$0.00
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:

Feedback

You are almost at the end of your final report. Before submitting, please take a few moments to provide some feedback.

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?
30000
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 we might consider:

InternetNZ is a membership organisation. Would you be interested in hearing more about becoming a member?
◉ Yes please ○ No thanks ○ I am already a member