SATELLITE AND SPACE COMMUNICATIONS **SSC**
http://committees.comsoc.org/ssc/

IEEE COMMUNICATIONS SOCIETY

SSC Newsletter **Vol. 24, No. 1, June 2014**

CONTENTS

The Satellite and Space Communications (SSC) Committee is a volunteer group actively involved in advancing satellite and space communication technologies within the IEEE. This committee is approved by the IEEE Communications Society and is governed by the constitution and bylaws of the IEEE as well as the other twenty-three Technical Committees in the Society. The committee belongs to the Technical Committee Clusters of Communication/Signal Processing (C/SP).

SATELLITE & SPACE

- JOIN US -

All conference attendees are welcome to join us in the SSC Committee meeting.
Location: Beaumont/Level 1, Sheraton on the Park
Date: Thursday, 12 June 2014
Time: 10:30-12:00

Future SSC Meetings
Dec. 2014, Austin, TX, USA
June 2015, London, UK
Dec. 2015, San Diego, USA

ICC 2014 SSC Committee Activities:

Symposium on Selected Areas in Communications:

- *Wednesday, 11 June 2014 • 14:30-16:00*
  Location: Level 1, Room 4
  SAC-SSC-01: Satellite and Space Networking
  Chair: Andreas Knopp (Munich University of the Bundeswehr & Institute for Information Transmission Systems, Germany)
- *Friday 13 June 2014 • 16:00-17:30*
  Location: Level 4, Room 4
  SAC-SSC-02: Satellite and Space Communications
  Chair: Tomaso De Cola (German Aerospace Center (DLR), Germany)

HOW TO JOIN SSC COMMITTEE AND MAILING LIST

If you like to join SSC Technical Committee: Please send your name and e-mail address to the SSC Secretary, optionally include your mail address, telephone and fax numbers.
If you like to join SSC Mailing List: Instructions on how to subscribe/unsubscribe are available at http://lists.scnl.dist.unige.it/listinfo/ssc/.

SSC COMMITTEE OFFICERS

CHAIR
Dr. Igor Bisio
Department of Telecommunication, Electronic, Electrical Engineering and Naval Architecture,
University of Genoa
Via Opera Pia 13, 16145, Genova, Italy
Tel: +39 010 353 2806
Fax: +39 010 353 2154
Email: igor@dist.unige.it

VICE CHAIR / EDITOR
Dr. Hiromitsu Wakana
National Institute of Information and Communications Technology (NICT)
4-2-1 Nukui-Kita, Koganei, Tokyo, 184-8795, Japan
Tel: +81-42-327-6026
Fax: +81-42-327-7605
e-mail: hwakana@nict.go.jp

SECRETARY
Dr. Tomaso de Cola
German Aerospace Center (DLR)
Munchnerstr. 20, Oberpfaffenhofen, 82234 Wesling, Germany
Tel: +49-8153-28-2156
Fax: +49-8153-28-2844
E-mail: tomaso.decola@dlr.de

PAST CHAIR
Prof. Nei Kato
Graduate School of Information Sciences
Tohoku University
Aoba 09, Aramaki, Aoba-ku, Sendai, 980-8579, Japan.
Tel: +81+22-795-6161
Fax: +81+22-795-6162
e-mail: kato@it.ecei.tohoku.ac.jp

COMMITTEE HISTORIAN
Mr. Louis Pollack
c/o Pollack Associates
15321 Delphinium Lane
Rockville, MD, USA 20853
Tel: +1 301 929 1295

COMMITTEE ADVISOR
Prof. Desmond P. Taylor
Dept. of Electrical & Electronic Engineering
University of Canterbury
Private Bag 4800
Christchurch, New Zealand
Tel: +64 3 364 2213
Fax: +64 3 364 2761
e-mail: taylor@elec.canterbury.ac.nz

MESSAGE FROM THE CHAIR

Prof. Igor Bisio

The Satellite and Space Communications (SSC) Technical Committee (TC) members will meet again during IEEE ICC2014 and it will be the last meeting steered by the current Officers Team that completes its term. During the meeting in Sydney, as decided during the last meeting in Atlanta, new election will be held and new Officers will be appointed for the next two-years term.

In this view, I want to deeply thank the members of the team, the Vice-Chair Dr. Hiromitsu Wakana and the Secretary Dr. Tomaso de Cola. I want to deeply thank also the Past Chair Prof. Nei Kato for his constant availability, advices and sageness. Their precious work has contributed to ward the existence of the committee in a period in which several difficulties arisen. Indeed, even if officially the SSC TC has been recertified by the IEEE ComSoc Technical Committee Recertification Committee (TCRC), a lot of work must be done in the imminent future to consolidate the historical presence of our TC in the framework of the IEEE Communications Society.

Obviously, we are proud to receive a positive answer concerning the recertification. It represents a stimulus to continue the effort of the SSC TC Officers and of the members that are cooperating in the many ongoing activities of the committee. The positive recertification is also a strong motivation to increase the obtained results and the SSC TC activity to reach the excellent level, usual for our TC, and to match the requirements highlighted in the review comments provided by the TCRC. I want to take the occasion to reports a summary of the answers, about many issues (highlighted in *Italic* in the following) provided to the TCRC that have allowed the recertification and that have to be carefully taken into account by the new Officers Team.

Aggregation with other TCs. We are strongly convinced that there is no overlap between the SSC TC and others such as Wireless Communications and Radio Communications. The SSC TC has a peculiar heterogeneity. Indeed, even if for historical reasons the name of the TC includes only the keyword “communications”, actually, it is composed of experts in the field of communications and networking. The proof is that, recently, the IEEE ComSoc GITC asks for three Symposium co-chairs candidatures: one for the SAC Symposium, where a dedicated track about SSC is always scheduled, and for the Wireless Communications and Wireless Networking Symposia. The Satellite and Space environment is a common area of interest for several researches in the communications, networking and other related fields linked to the Electrical and Electronic Engineering.

An aggregation under the sole umbrella of the Wireless Communications (or Radio Communications) could imply the migration of many members because they cannot find a common area of interest represented by the Satellite and Space environment. For example, the members of the community working on satellite networking issues could leave the IEEE Communications Society towards others.

Participation to TC Meetings. The average number of attendees is really low. Actually if the meeting agenda do not include delicate issues, usually the attendants number is not so high. In other case, for example in case of officer elections (not in the last two cases because the elections took place electronically) the number of attendees is significant. Anyway, understood the importance of the presence to the SSC TC meetings, the last meeting, held in Atlanta during IEEE GLOBECOM 2013, had around 40 attendees.

A second reason of the limited participation to the meetings is the travel costs. In the last years, a lot of academic and industry institutes dramatically reduced the travel costs. Unfortunately it has an impact to the conference, and meeting, participation. Considering again the importance of the meeting attendance for the next meetings, the virtual presence for those members that, for cost related reasons, cannot attend will be realized starting from the meeting held during IEEE ICC2014 in Sydney.

Operative Policies and Procedures (OP&P). The SSC TC had OP&P not completely coherent with the ComSoc rules. Modifications of the OP&P have been carefully taken into account and discussed in the last meeting in Atlanta and approved. The final document, revised by the Past VP-

TA Len Cimini, has been sent to the current VP-TA Khaled Letaief and to the IEEE ComSoc to update the related website. The delicate Voting Member issue has been addressed: the definition (coherent with the ComSoc by-law) is provided and the list of voting members has been prepared and employed for the election held during IEEE ICC2014.

Membership Management. As the TCRC highlighted, the SSC TC has a good number of members. A future action should be two-fold: to continue with the acquisition of new member and, more important, to involve old and new members in the TC activities (as Symposium Chairs, Guest Editors, etc.).

Extended Cooperation. The specific nature of the SSC TC allows significantly extending the cooperation. A strict cooperation with Industries, research institutes, standardization institutes (e.g., CCSDS, ETSI), space agencies of several countries (NASA, JAXA, ESA) is necessary. Other important cooperation could be began with the AIAA and other similar societies with common interest in the satellite and space communications and networking fields.

Review of the Advisory Committee. Coherently with the previous points, the Advisory Committee must be reconsidered. It will be evaluated in the next meetings of the SSC TC. The involvement of new members for those roles will be considered highly welcome to increase the level of involvement in the TC activities.

SSC Website and Mailing List. The SSC web site under a partial revision. Considering the websites of other TCs, I think that only the essential information can be provided (the one needed by following the ComSoc P&P). The Secretary has evaluated the other TCs' websites and will propose possible modifications for the next-term Secretary.

Current Journals/Magazines. As mentioned several times, two editorial initiatives have been promoted: one in IEEE Communications Magazine (COMMAG) and one in the IEEE JSAC. The former has been publicized since months and the deadline is July 1st, 2014. Please submit your papers. The success of the initiative is important for our TC. The latter is still under evaluation by the JSAC editorial board that, due to the change of the editorial team, needs more time and information to approve (or not) the special issue proposal. I would thank Prof. Sacchi and Prof. Vanelli-Coralli and their teams for the work around to these initiatives.

Conference Activities (ICC/GC and others). In ICC/GC is consolidated the SSC Track. In the recent years the SSC track has been quite successful. In the future, officers and active members must cooperate in the dissemination of the CFP so avoiding an oscillating trend of the number of submission. An average of 50 submissions should be guaranteed in the future. It guarantees a “long life” of the track. Recently, moreover, the SSC TC is asked to propose candidatures for the Wireless Networking and Wireless Communications Symposia. It increases the involvement of members.

Finally, the SSC TC is recently endorsing several interesting conferences for the IEEE ComSoc Technical-Co-sponsorship. In the last two years 3-5 conferences have been endorsed, In all of them several members of the SSC TC are actively involved in the organization.

Awards and Distinguished Lecturers. The SSC TC will work on two kinds of awards: the SSC Awards and the other

IEEE/ComSoc Awards. The SSC Award rules have been recently restructured. Its current rules' structure does not need any revision. Concerning the second kind, the SSC TC will be more active in advancing members for IEEE/ComSoc awards and as Distinguished Lecturers. An ad-hoc committee will be appointed to work on this issue in the next months. The subcommittee will have the duty to individuate, among the SSC active members, the highest scientific profiles to be proposed for the important IEEE/ComSoc Awards and for the Distinguished Lecturers role.

Standardization Activities. The TC should make a stronger effort to get involved in standards activities and to actively recruit industry participation in the TC. During the last meeting, we appointed the Standard Liaison:

Henry Suthon, P.E.
Barrios Principal Senior Engineer
Boeing C&DH Subsystems
International Space Station
email: h.suthon@ieee.org

It has been communicated to the IEEE ComSoc Executive and administrative support to update the ComSoc website.

The mentioned issues and other minor ones, not reported for the sake of brevity, represent a significant amount of work for the new Officer Team that will need the strong cooperation of all the members of the SSC TC for a successful final result and for the consolidation of the SSC TC in the framework of the IEEE Communications Society.

Prof. Igor Bisio, Chair
Satellite and Space Communications TC

SCANNING THE WORLD

Dr. Hiromitsu Wakana

Japan Aerospace Exploration Agency (JAXA) provides opportunities for piggyback launch of microsatellites, less than 50 kilograms in weight and $(50cm)^3$ in size, to Japanese universities and private companies. JAXA intends to contribute to human resource development and R&D in space education and technology fields. In 27 February 2014, seven microsatellites were launched together with the Global Precipitation Measurement (GPM) satellite: STARS-II of Kagawa University, TeikyoSat-3 of Teikyo University, ShindaiSat of Shinshu University, KSAT2 of Kagoshima University, INVADER of Tama Art University, OPUSAT of Osaka Prefecture University, and ITF-1 of University of Tsukuba. These microsatellites have various designs, which suit their unique missions and specific functions.

STARS-II, which consists two separate spacecraft units joined by a tether (300m in length), will test deployment of the tether in space and electric currents induced by the Earth's magnetic field. TeikyoSat-3 investigates the effects of space conditions such as microgravity and cosmic radiation in cell growth of dictyostelium discoideum. ShindaiSat conducts bidirectional visible light communications using high-gain LED with 32 parabolic mirrors (6^o irradiation angle) for transmit and 80mm-in-diameter optical lens for receive. KSAT-2 conducts in-orbit observation of atmospheric water vapor, rainfall and tornado, and transmits Earth live images from Space in Ku band. INVADAR (interactive satellite for Art and Design Experimental Research) is the first mission of the "ARTSAT: Art and Satellite Project", which utilizes an earth-orbiting satellite as a "medium that connects everyday life to the universe". Sensors for art work, a low resolution camera, and a Digi-Talker are equipped. OPUSAT (CosMoz) demonstrates an advanced hybrid powersupply system using lithium-ion capacitors and lithium-ion batteries, which enables long-term operation for high power discharge and deep charge-discharge cycle applications. A spin stabilization system using magnetic torquers is also equipped. ITF-1 will establish a world-wide network of amateur radio operators, and sends telemetry by a Morse Code audio tone on an FM transmitter.

Very recently, in 24 May 2014, four microsatellites were successfully piggyback launched with the Advanced Land Observing Satellite, ALOS-2, by H-IIA rocket. One of four microsatellites is Space Optical Communications Research Advanced Technology Satellite (SOCRATES), which is a mission of National Institute of Information and Communications Technology (NICT) to demonstrate and validate the operation of Small Optical TrAnsponder (SOTA), optical communication system in space.

It is said that satellite communications is the most mature area of the space applications. One reason, however, is the lack of opportunity for researchers to launch their developed satellites with new ideas and concepts. I believe that such small satellites lead innovation of new satellite communication technologies, because of low costs, and quick development.

NICT organizes the *BroadSky Workshop* in cooperation with the *Ka and Broadband Communications, Navigation and Earth Observation Conference*, which is held once every year. In 2013, the BroadSky Workshop themed “Small Satellites, Big Possibilities”. The invited speakers came from ISAS/JAXA of Japan, Surrey Satellite Technology Limited of UK, Orbital Science Corporation of USA, Busek Co. Inc. of USA, Italian Space Agency of Italy. Although the detailed information will not be given here due to lack of space on the page, a wide variety of small satellites with unique functions and objectives is being operated and planned to be launched. I am looking forward to seeing new advanced satellite communication technologies to be tested in space.

Dr. Hiromitsu Wakana, Vice Chair
Satellite and Space Communications TC

FORTHCOMING GLOBECOM AND ICC CONFERENCES

COSPONSORING / RELATED CONFERENCES AND WORKSHOPS

MILCOM 2014
October 6-8, 2014, Baltimore, MD, USA
http://www.milcom.org/

The MILCOM 2014 - Military Communications Conference is dedicated to military communications networking, services, timing and applications, including:

Waveforms and Signal Processing view details
Selected Topics in Communications view details
International Perspectives on Communications
Networking Protocols and Performance view details
Services and Applications view details
Cyber Security and Trusted Computing view details
System Perspectives view details

The MILCOM 2014 - Military Communications Conference brings together professionals from the industry, academia, and government.

GLOBECOM 2014
December 8-12, 2014, Austin, TX, USA
http://www.ieee-globecom.org/2014/

IEEE GLOBECOM is one of two flagship conferences of the IEEE Communications Society, together with IEEE ICC. Each year the conference attracts about 3000 submitted scientific papers. A technical program committee of more than 1,500 experts provides more than 10,000 reviews, and from this a small fraction of the submitted papers are accepted for publication and presentation at the conference. The conference meets once a year in North America and attracts roughly 2000 leading scientists and researchers and industry leaders from all around the world. IEEE GLOBECOM is therefore one of the most significant scientific events of the networking and communications community, a must-attend event for scientists and researchers from industry and academia.

ICC 2015

June 8-12, 2015, London, UK

http://www.ieee-icc.org/2015/

The IEEE International Conference on Communications (ICC) will be held in London, UK from 8-12 June 2015. Themed "Smart City & Smart World," with its proximity to London's Tech City, the fastest growing technology cluster in Europe, this flagship conference of IEEE Communications Society will feature a comprehensive technical program including twelve Symposia and a number of Tutorials and Workshops. IEEE ICC 2015 will also include an exceptional Industry Forum & Exhibition program including business panels and keynote speakers. We invite you to submit your original technical papers, and industry forum, workshop, and tutorial proposals to this event. Accepted and presented papers will be published in the IEEE ICC 2015 Conference Proceedings and submitted to IEEE Xplore®.

CONFERENCES CALENDAR

CONFERENCE	DATE & LOCATION	INFORMATION
International Conference on Localization and GNSS	June 24-26, 2014 Helsinki, Finland	http://www.icl-gnss.org/
SPECTS 2014 International Symposium on Performance Evaluation of Computer and Telecommunication Systems	July 6-10, 2014 Monterey, CA, USA	http://atc.udg.edu/SPECTS2014/
CITS 2014 International Conference on Computer, Information and Telecommunication Systems	July 10-11, 2014 Jeju Island, South Korea	http://atc.udg.edu/CITS2014/
ASMS/SPSC2014 7th Advanced Satellite Multimedia Systems Conference & 13th Signal Processing for Space Communications Workshop	September 8-10, 2014 Livorno, Italy	http://www.asms2014.org/
19th **Ka and Broadband** Communications Navigation and Earth Observation Conference 2013	October 1-3, 2014 Salerno, Italy	http://www.kaconf.org/
ITST-2014 International Conference on Telecommunications for Intelligent Transport Systems	2014 TBD	http://
IEEE Aerospace Conference	Mar 7 - 14, 2015 the Yellowstone Conference Center in Big Sky, Montana, USA	http://www.aeroconf.org/
WCNC 2015 IEEE Wireless Communications and Networking Conference	March 9-12, 2015 New Orleans, LA, USA	http://wcnc2015.ieee-wcnc.org/

To all SSC members: If your postal address, telephone or fax numbers have changed, please update them with the committee secretary. You can review our current records on our web page at http://committees.comsoc.org/ssc/.

Network Construction with Unmanned Aerial Vehicles for Disaster Areas

Daisuke Takaishi[1], Hiroki Nishiyama[1], Nei Kato[1], Fumie Ono[2], and Ryu Miura[2],
[1] Graduate School of Information Sciences, Tohoku University, Sendai Japan
E-mail: {takaishi, bigtree, kato}@it.ecei.tohoku.ac.jp
[2] National Institute of Information and Communications Technology, Tokyo, Japan
E-mail: {fumie, ryu}@nict.go.jp

Abstract — **The research and development of network construction with Unmanned Aerial Vehicles (UAVs) has been conducted to enable users to utilize the conventional network services just after natural disasters. In our projects, we carried out the communication experiment with UAV. From the experimental result, we revealed the research topic and future networks.**

INTRODUCTION

The Great East Japan Earthquake and Tsunami on March 11th 2011 caused damage in the wide area of Northern Japan. In the damaged areas, not only public infrastructure such as electric power lines, water infrastructure, and so forth but also most of network infrastructure such as cellular base stations, network cables, and so forth are destroyed or left non-functional. Due to the cease of functionality of the network infrastructure, victims in the disaster area were not able to get in touch with families and friends in addition to not having means of knowing the important information regarding refuge area and relief aid. Moreover, this made it difficult to assess the actual disaster situation. This results in inefficient rescue.

Because of such a scenario, the Japanese government, corporations, and academic institutions are trying to develop a novel network system that can be used after natural disasters. Unmanned Aerial Vehicle (UAV) equipped with communications functionality is a promising system to provide disaster resilient network services. Because UAVs fly over the disaster area even in scenarios' where road conditions render deploying vehicle-type communications infrastructure not possible, victims can transmit (or receive) the data to (or from) other areas through the remaining functional infrastructure and the UAVs, as shown in Figure 1. Therefore, the victims can get in touch with families and friends. Moreover, because a UAV can be quickly deployed to disaster area and easily launched by hands, it is adequate for gathering environmental information which is generated by sensors in the disaster area. The collected information helps facilitate rescue operations.

In our R&D project, we propose a next generation network with UAV such as system design, development of devices, communication architectures and so forth. Moreover, we conduct the communication experiment with real UAV to know the actual performance of UAVs' data relaying systems. From these experimental results, we sophisticate the proposal next generation networks.

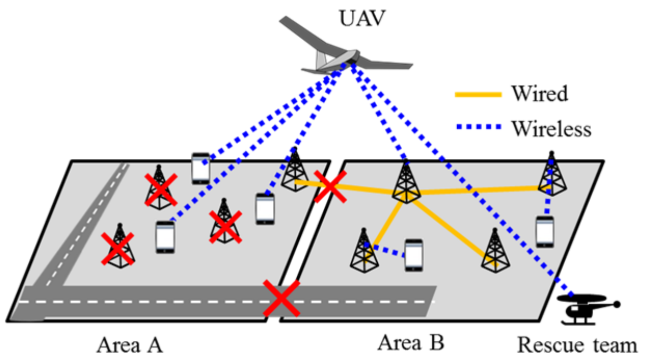

Figure 1. The UAV relaying system over the disaster areas.

OVERVIEW OF THE SYSTEM

An Overview of our Unmanned Aircraft System (UAS) is shown in Figure 2. Our employed UAV is equipped with a flight module and a wireless communication module. Because the trajectories of UAV can be controlled in response to the situation of the disaster area, this system provides efficient data communication between users by controlling the UAV. This system is consist of an UAV that provides communication between distant areas, ground antennas for transmitting data to the UAV (referred to as "Payload ground station"), a ground antenna for controlling the UAV (referred to as "UAV control station"). In the remainder of section, we present the UAV control function, communications function between distant areas, and communications function of the users.

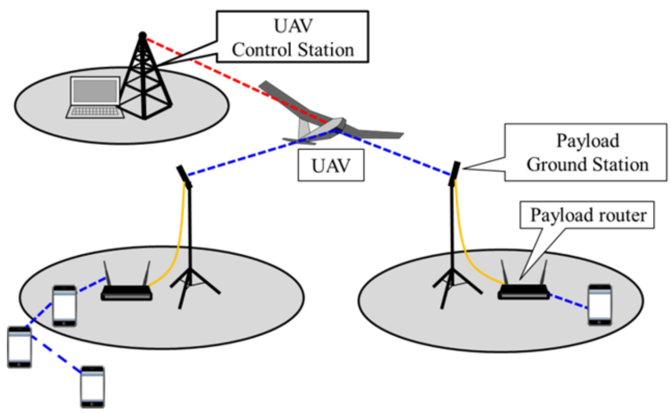

Figure 2. System overview of UAS.

Figure 3. Small fixed-wing UAV.

1) UAV control function

In this system, we can dynamically control the UAV's mobility (i.e., trajectories, altitude speed and so forth) by using the control signal, which is transmitted from the UAV Control Station. The flight trajectory information is summarized in Table 1. In fact, the UAV's mobility is decided on the application of electrical map. The mobility information is converted to the GPS information. Then, the UAV control station transmits the GPS information to the UAV. The wireless transmission information is summarized in Table 2. After receiving the information, the UAV flies according to the new trajectory information. In the event of an emergency situation, "Go home mode" can be used. This mode automatically creates the trajectory of UAV for homing and transmits it to the UAV. In addition to the above mentioned "real time flight mode", we can set the mobility of UAV beforehand (referred to as "preset flight mode"). In this mode, the UAV control station is not required and the UAV autonomously flies following pre-set GPS information.

Table 1. Specifications of the flight [2].

Flying speed	37-83km/h
Flying range	15km
Altitude	0-500m
Endurance	2hours

2) Communication function between distant areas.

In addition to UAV control function, this system provides communication between distant areas. To utilize this function, the payload routers are deployed to provide users connectivity with Wi-Fi. The data received by the payload router are transmitted to UAV via the Payload Ground Station. Then, the data are relayed to another Payload Ground Station in remote area. After that, the data are transmitted to the users or the Internet via the Payload Ground Station and Payload router. Because the antennas of the Ground Station are directional antenna, antennas are according to the direction of UAV with line-of-sigh to successful data communications. Detailed information of the communication is shown in Table 2.

Table 2. Specifications of the transmissions.

Transmission for the trajectory control	Uplink Frequency	400MHz
	Downlink Frequency	1800MHz
Data transmission	Frequency	2GHz
	Multiple access	TDMA/TDD

3) User Access networks

In this system, the payload routers are deployed to distinct area to provide data communication service to user devices. Additionally, since the Payload router in distant areas communicate through the UAV. However, in the real situation, due to the limitation of the number of the Payload router, all the users cannot connect to the Payload router. In order to ensure the connectivity between users and the Payload router, we also develop user access networks.

One of our considered solutions is Wireless Mesh Network, which is constructed by using the remaining base station of mobile network operators and WiFi routers. As other solution, we have developed the Device-to-Device communication application (referred to as "Relay-by-Smartphone") [1]. In this system, because each user device operates similarly to the router, the sender can transmit data to the Payload router. Furthermore, each user, which is implemented Relay-by-Smartphone system, can freely choose the communication modes (i.e., Mobile Ad-hoc Networks (MANETs) and Delay Tolerant Networks (DTNs)) in response to the network environments (i.e., user density, user mobility, user battery). This results in increase of the transmission success ration with higher energy and communication efficiency.

Field Experiment

1) Experimental Scenario

We conduct the field experiment which is modeled after a disaster scenario. Figure 4 shows the experimental scenario and the experimental field. We suppose that after a disaster the network environment that includes disaster area and non-affected area. In the disaster area, due to the devastation of network infrastructures, the users cannot utilize conventional network services via the Internet. On the other hand, in the non-affected area, connections to the Internet are not disconnected.

In the experiment, we deployed a UAV over the supposed disaster network infrastructures with a circular topology as shown in Figure 4. The UAV is configured to repeat the circular trajectory and keep an altitude of 300m. The Payload Ground Station and Payload router are deployed at the center of disaster area and non-affected area. Each UAV antenna set on the top of the building with the direction of the UAV. By flying over the supposed disaster area with a circular trajectory, the UAV can always provide users of the network connectivity to the Internet. The generated data by users in Aobayama Campus which is an area that takes the role of disaster area, are transferred to the Payload router deployed at center of the campus. However, due to the limited transmission range of a Wi-Fi, some users cannot connect to the gateway directly. Then, we construct Mobile Ad-hod Network (MANET) with Relay-by-Smartphones to connect the gateways. The received data by Payload router are transferred to the UAV via the Payload ground Station. Then, the UAV relays the data to the Katahira Campus, which is an area that takes the role of non-affected area. Finally, the data are transmitted to the Internet or destination smartphones via the Payload router. These two campuses have the distances of about 2.5km.

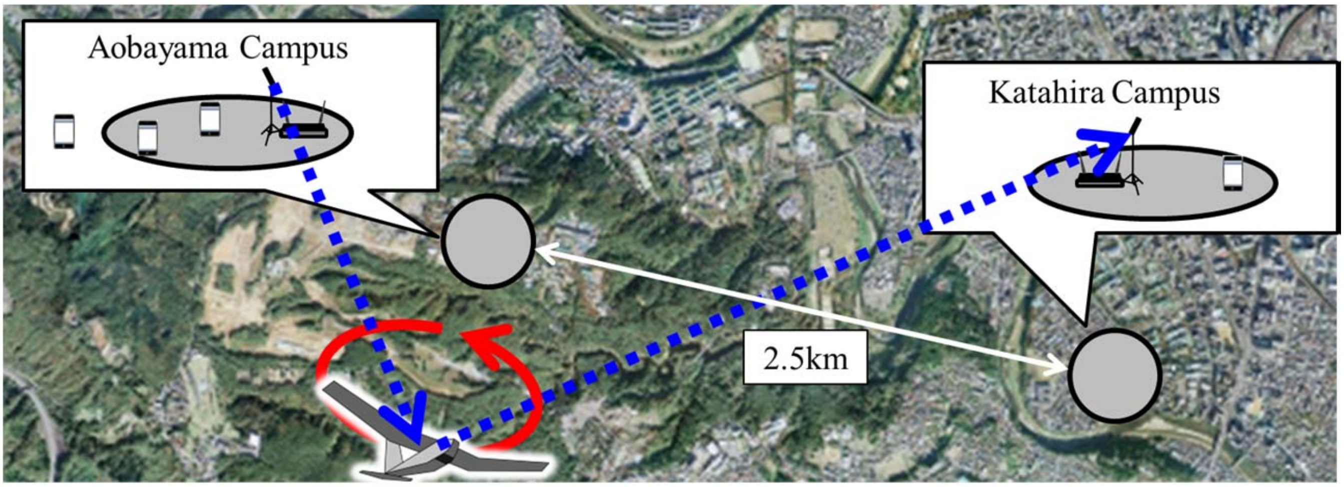

Figure 4. Network experimental scenario.

2) Experimental Result

In the first experiment, we conducted the communication experiment along with the experimental scenario. We have attempted to use network services, which include E-mail and Web browsing in Aobayama Campus. In this experiment we have observed wireless signal at the Payload ground stations when we tried to use the e-mail application or web browsing applications. Then, the network services are successfully executed on the user terminal.

In the second experiment, we have conducted communication performance measurements. By using the e-mail application with varied size of attached filed, we have attempted to measure the End-to-End delay. Throughout the experiment, the same network topology and same devices are used. The destination of data transmitted from smartphone is in Katahira Campus. The measured End-to-End delay is shown in Figure 5. As shown in Figure 5 the average End-to-End delay becomes bigger with the increase of attached file size. Moreover, there are variations of the delay. These are caused by relay transmissions of Relay-by-Smartphone, and not the UAS, according to the experiment that indicate similarity of the result to the experiment which is intended to measure the performance of Relay-by-smartphone system. We will measure the delay between Payload ground stations.

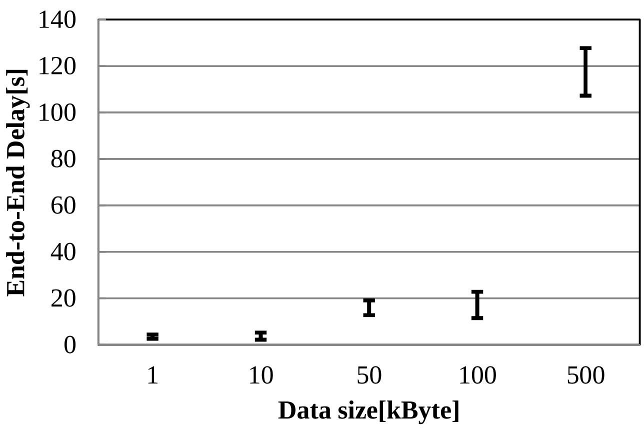

Figure 5. Transmission delays between users

Research & Future Work

1) Implementing DTN on UAV

Because communications between UAV and Payload Ground Stations are conducted by a wireless interface, there is a limitation of maximum communication distances. If the target areas are smaller than maximum communication distances, all of the payload ground station in the target area can be covered by a UAV. The generated data from users are successfully relayed to other payload ground stations. However, in case that the targeted areas are larger than the limited maximum communication distance or the distances between the disaster area and the unaffected area are large, the data relay fails.

DTN is a useful network system that stores the data until that the neighboring network nodes enter its communication range. Then, it realizes data relay in the various environments such as lack of network infrastructures, large target area, and so forth. DTN functionality is expected to be installed into UAV. By using DTN, the UAV becomes able to carry the data that is sent from ground network to another ground network by using its mobility. However, the mobility speed of UAV is slower than the wireless transmission. Then the End-to-End delay becomes bigger if the distance of carrying data is big. The user's waiting time from data generation to data transmission become bigger too. This is because the UAV does not always fly nearby users. Thus, users need to wait until UAV enter to its communication range.

To reduce the sum of End-to-End delay of users, some solutions can be considered. Improving the UAV's flying speed and shortening the length of UAV's trajectory path are simple but effective solutions. For realizing these solutions, we need to design the UAV's mobility decision schemes such that the restrictions such as covering all of target area, and no-failure in communication between UAV and Payload ground stations are meet.

2) Constructing UAV networks

Meeting requirements of UAV is the most important challenging issue in the design of UAV data relaying system. The requirements are different for each application and each network status. In case that users use the real-time applications such as Voice over IP (VoIP) or video conferencing systems, The UAV network need to have the stable connectivity. In case that much volume of data is generated from one place to another, the UAV network should be constructed to relieve the traffic congestion.

Constructing UAV networks with multiple UAVs are one of the expected network forms to achieve high performance network over the target area. In a multiple UAV network, each UAV connects to the neighboring UAVs which are in a communication range. The transmitted data from ground networks are relayed through these UAV-to-UAV links in a multi-hop fashion as shown in Figure 6. Compared to single-UAV relaying system, the multi-UAV relaying system can cover the wide area with no intermittent communication. Compared to a single-UAV relaying system with DTN, since each UAV transmits the data to neighboring UAV with no store-and-carry, the End-to-End delay can be reduced.

To achieve these goals, the UAV network should be constructed according to the expected UAV network performance. Especially, the UAVs' mobility is known as the most affective factor to decide the network performance. For example, if the neighboring UAVs fly with no consideration of neighboring UAVs' trajectory, the UAVs will never enter to the communication range. Then user cannot use some network services that use End-to-End connection since the End-to-End communication links are not connected.

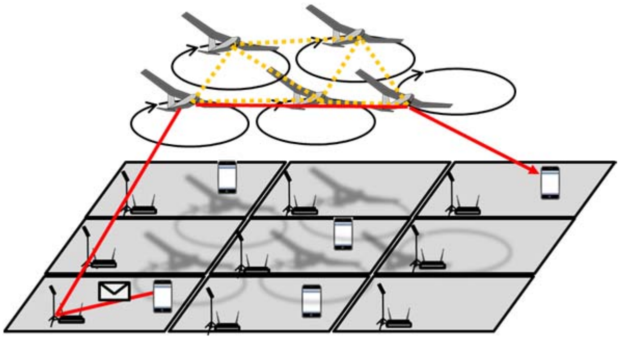

Figure 6. UAV Network with multiple-UAVs

3) Cooperation with the various types of ground networks

As a future of anti-disaster networks, the UAV relaying systems are expected to enable users to communicate with UAV directly. With direct communication between users and UAV, UAV relaying system can get some advantages compared to present UAV relaying system. At first, more prompt network constructions can be enabled because the Payload routers and the antennas are not necessary to be deployed (i.e., only the launching UAV is needed.). Then the victims in disaster areas can use the network services just after the occurrence of natural disaster. To meet these network requirements, UAVs are needed to be equipped some wireless communication modules such as Wi-Fi. The second advantage of using direct communication between users and UAV is to be able to prevent performance degradation caused by the ground networks. Especially, in the disaster area where the lack of network infrastructure and damage caused to the equipment reduce the network performance of ground network to lower than usual. By implementing the direct communication between users and UAV, users can send the data directly to the UAV without using the ground networks.

Moreover, UAV is anticipated to connect with various types of ground networks such as Wireless Sensor Networks (WSNs), WMNs and so forth [3]. By communicating with these ground networks, novel UAV applications are enabled. For example, the network can collect data from coast area and mountains where the network infrastructures are not installed. And at event areas, where the cellular networks are congested with user traffic, UAVs can relay the data from users to not congested cellular network as alternative networks. Therefore, to cooperate with these networks, UAV is needed to enable communicate with conventional ground networks in terms of communication protocol, IP address, routing and so on.

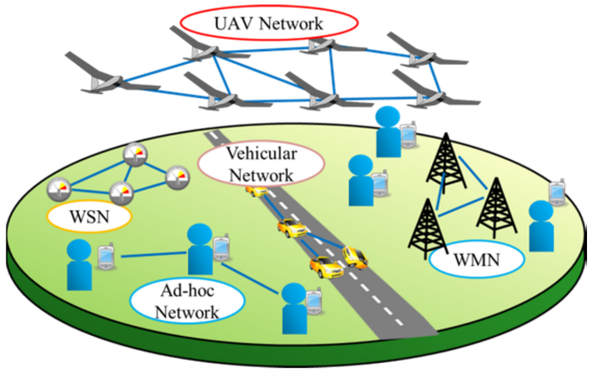

Figure 7. Future UAV Networks with ground network

Conclusion

UAS is a versatile system, which has many possible applications. We have explored the potential of the UAV relaying system, which is one of the key technologies for interconnecting remote multi-hop wireless networks. The practicality and performance of UAS based relay when integrated with Relay-by-Smartphone is demonstrated. Finally, we point out some issues in order to improve the performance of UAV relaying systems in the future.

Acknowledgement

Part of this work was conducted under the national project, Research and Development on Cooperative Technologies and Frequency Sharing Between Unmanned Aircraft Systems (UAS) Based Wireless Relay Systems and Terrestrial Networks, supported by the Ministry of Internal Affairs and Communications (MIC), Japan.

References

[1] Hiroki Nishiyama, Masaya Ito, and Nei Kato, "Relay-by-Smartphone: Realizing Multi-Hop Device-to-Device Communications", IEEE Communications Magazine, vol. 52, no. 4, pp. 56-65, Apr. 2014.

[2] AeroVironment, "Technical Specifications PUMA AE," http://www.avinc.com/downloads/AV_PUMAAE_V10109.pdf

[3] Daisuke Takaishi, Hiroki Nishiyama, Nei Kato, and Ryu Miura, "Towards Energy Efficient Big Data Gathering in Densely Distributed Sensor Networks," IEEE Transactions on Emerging Topics in Computing (TETC), 2014