Short Term Scientific Mission (STSM) Report for COST CA15127 Action: RECODIS

STSM Title: Integration of Earthquake Early Warning Systems and Optical Network - Part I		
STSM Applicant: Ferhat Dikbiyik (TR)	**Period:** Nov. 13 – Nov. 20, 2016 (8 days)	**WG1**
Host: Seismological Lab. of the Dept. of Physics (RISSC Lab) at the Univ. of Naples Federico II (IT)		

Purpose of STSM

Earthquakes cause huge data loss when a major ground motion strikes backbone telecom infrastructure. However, necessary actions can be taken if an earthquake early warning system is integrated to optical WDM networks, which is the typical architecture of backbone telecom networks. While earthquake early warning systems are used to provide warnings to railway transportation, nuclear power plants, or semiconductor factories, they have been not used to provide warnings to telecom networks. However, many connections can be reprovisioned to avoid data loss in case of a disaster if a warning is provided seconds before a major earthquake. The problem itself requires a multidisciplinary work between researchers from communication and seismology fields. In that sense, the experts from those areas can provide more realistic and implementable research work. The goal of this STSM is to bring people from different fields to provide solid solutions to the problem, to exchange research focus and learn the research methodology of earthquake monitoring and early warning systems, to discuss the benefits to have an integration between early warning systems and optical networks, to observe and get to know the hardware and software used for earthquake monitoring and early warning systems, discuss on how to integrate an earthquake early warning system to an optical network and to provide basic theoretical background for such integration, and to create a work plan on outcomes of work collaboration in terms of publication, patent, design along the line of goals of RECODIS action.

Description of the work carried out during the STSM

During the STSM visit, the research carried out in two different fields by the applicant and host (seismology and telecommunication) were exchanged. Then, several collaboration topics were discussed. We narrowed them down to three main topics.

1. Use of Earthquake Early Warning Systems (EEWS) to provide better preparedness of optical networks against large-scale earthquakes,
2. Use of shake maps generated right after earthquake to provide a better recovery plan for optical networks, and
3. Measurement of seismic movements through fiber optical networks.

A visit to Dr. Andrea Irace’s lab, who is an Assistant Professor of Analog Integrated Circuits in Dept. of Electrical Engineering and Information Technology at the University of Naples Federico II, was conducted. Dr. Irace works on fiber optics sensors to monitor health of a structure and he showed us how these fiber optic sensors work. A discussion on how the seismic waves affect the signal quality or create wavelength shift in the fiber and the use of fiber optic sensors on fiber optic cables to seek the opportunity to use optical networks to monitor seismic movements is made.

The descriptions of each topics discussed are given below.

1. Use of EEWS to provide better preparedness of optical networks against earthquakes;

EEWS can provide warning for an upcoming earthquakes to a certain location with a certain peak ground acceleration (or peak ground velocity), a parameter helpful to estimate the intensity of earthquake at the location interested. If such warnings can be given to optical network operator for their optical components such as optical nodes and fiber optic cables, then better preparedness strategies can be developed. In order to that, the effect of a seismic movement with a certain peak ground acceleration (or velocity) should be known as a priori. To create fragility curves for optical networks will be extremely useful to understand the effect.

EEWSs have different types and accuracy and time window to be prepared depend on many parameters. The conducted examples should cover these effects as well. For instance the two methods used by RISSC Lab (network-based and on-site approaches) have certain advantages and disadvantages. Network-based approach provides warnings for a remote facility to be protected by using sensed information from several stations. For the facility, the time window will be larger compared to on-site approach, but accuracy is less. On the other hand, on-site approach uses a station on the site of facility to detect primary waves, so accuracy is more improved, but the time window is narrower. All these aspects should be considered.

Besides, the cost of missed alarm and false alarm for an optical network operator should also be investigated. The time complexity required for re-provisioning of connections to avoid loss in the time interval between warning time and strong ground motion arrival should be investigated.

2. **Use of shake maps generated right after earthquake to provide a better recovery plan;**

After an earthquake a shake map is generated that shows the intensity of earthquake in different regions with some certainty. Since the intensity is known (rather than a estimation), the damage on optical networks can be estimated more precisely and relevant actions can be taken. However, after an earthquake hits a certain area, in couple of minutes, correlated failures occur, such as power outage (it can be also an intentional power cut rather than failure to avoid certain fire risks and damage on electrical equipment). If an optical node is functional after an earthquake, it may be not operational due to power outages right after the earthquake. Some network equipment may run on diesel generators, but (as reported in recent disasters), generators may also fail. In that case, network operator may want to take necessary actions based on the information given by shake map before correlated failures occur. Therefore, the sooner the shake map is generated, the faster the actions can be taken. Surely, generating shake maps in a short time window may cause some inaccuracy in data, so this effect should also be investigated.

3. **Measurement of seismic movements through fiber optical networks;**

Since the perturbation of the optical cables creates a reduction in the performance (quality of transmission) or creates a shift in wavelengths, in principle, we should be able to detect the earthquake origin, locate it and track the propagation of largest wave amplitudes over the optical networks. Therefore, an optical backbone network (maybe with the use fiber optic sensors placed over the cables) may be used as a nation-wide seismic monitoring system.

In order to investigate the possibility of such system, following questions should be explored:

- What are the effects of seismic waves on optical cables?
- Would the effects for small-size ground motion be detectable? What is the sensitivity?
- How to correlate the effect with peak ground acceleration?
- The type of fiber, the type of coating/protection layers, the location of cable (under different types of soil, attached to walls of sewer canal, attached under a bridge, etc). How do all these parameters affect the degradation?

In order to answer all these questions, a physical experimental setup should be provided. One way of doing such experiments is to playback recent earthquakes on a shaking table on which optical components placed. Since the length of the optical cable used in this experiment would be much shorter than a realistic scenario, some inaccuracies may occur. Another way is to lay a long cable (100s of km) over a very active seismic fault line and observe the effect in real time. We consider, the west part of North Anatolian Fault Line would be a good option for such experiment. This work can be a good research topic for a separate EU project. Estimated time to complete 2-4 years.

Description of main results obtained and future collaboration with the Host institution

Work	Basic idea	Methodology	Goal	Outcome
Create preparedness strategies considering an integration between EEW and optical networks exists (estimated time to complete 2-6 months)	We will consider that an optical component is down when PGA (or PGV) value is above a certain threshold.	- Calculation of economical loss when an optical component fails (Sakarya Uni.) - Creating case studies by past earthquakes and simulated earthquakes (RISSC Lab) - Developing algorithms for preparedness in optical networks (Sakarya Uni.) - Simulations will be done by conducting examples by different threshold values with two different EEW strategy, network-based and on-site (Sakarya Uni. and RISSC Lab.) - The results will compare loss for an optical network integrated with EEWS vs. one without integration (Sakarya Uni. and RISSC Lab.)	To show the effectiveness of such integration	A journal paper (may also provide some conference papers) Preliminary results for application to a EU projects
Improve results by using more realistic value for damage vs. PGA with empirical data (estimated time to complete 2-6 months)	We will consider that an optical component partially or totally down by seismic waves. The damage will be computed by fragility curves created by empirical data.	- Obtaining data loss values and network element locations from an Italian network operator during the earthquake on October, 30, 2016. (Sakarya Uni., possibly Politecnico di Milano) - Correlating the results with seismic activities at the locations of network elements to create empirical fragility curves. (RISSC Lab. And Sakarya Uni.) - Developing more intelligent algorithms for preparedness in optical networks (Sakarya Uni.) - Simulations will be done by conducting examples with two different EEW strategy, network-based and on-site (Sakarya Uni., RISSC Lab., and possible Politecnico di Milano) - The results will compare loss for an optical network integrated with EEWS vs. one without integration. Further comparison can be done for parameters related to EEW systems such as number of stations, distribution of stations, etc. (Sakarya Uni. and RISSC Lab.)	To show the effectiveness of integration with empirical data, and also create more intelligent strategies.	Two or more journal papers, several conference paper. The results will be used for EU project application, if a proper call is found.
Create real fragility curves by physical experiments (estimated time to complete 1-2 years)	We will create fragility curves by placing optical cables and optical nodes on shaking tables and observing the effect through fiber optic sensors and OTDR	- Creating basic network setup settings that include several different optical network components (fiber optic cable, OXC, EDFA, etc.). (Sakarya Uni., possibly Politecnico di Milano) - Placing fiber optic sensor over these settings (Sakarya Uni., UNINA Engineering Faculty) - Placing these settings to shaking tables (Sakarya Uni., UNINA Engineering Faculty) - Creating a monitoring field experiment on a seismically active region (e.g., North Anatolian Fault Line) by placing seismic stations and fiber optic sensor over fiber optical cables. - Correlating data of seismic waves to data loss to create the fragility curves (Sakarya Uni., RISSC Lab., and possible Politecnico di Milano) - Use of new fragility curves for strategies created above	To increase the realistic nature of the study Such fragility curves are not provided before.	This work has to be a funded project (hopefully an EU project), because it requires money.

Work	Basic idea	Methodology	Goal	Outcome
Create re-provisioning strategies by using information by shake maps (estimated time to complete 2-6 months)	We will consider to develop strategies of re-provisioning of connections by using example shake maps and correlation between intensity vs. damage	- Generating/finding case study shake maps by past earthquakes and simulated earthquakes (RISSC Lab) - Developing algorithms for re-provisioning in optical networks (Sakarya Uni.) - Simulations will be done by conducting examples with different shake maps (Sakarya Uni. and RISSC Lab.) - The results will compare loss for an optical network with shake-map awareness and shake-map unawareness (Sakarya Uni. and RISSC Lab.)	To show the effectiveness of shake map use for optical networks	A journal paper (may also provide a conference paper)
Improve results by using shake maps generated in different times (estimated time to complete 2-6 months)	We will investigate the effects of time that shake-map generated, the time required for re-provisioning, the loss (due to late re-provisioning)	- Creating methodology on generating shake maps earlier (RISCC Lab.) - Creating scenarios for correlated failures after an earthquake (Sakarya Uni. and RISSC Lab.) - Developing intelligent strategies when the time window is known (or estimated) (Sakarya Uni.) - Simulations will be done by conducting examples with different case scenarios (Sakarya Uni., RISSC Lab., and possible Politecnico di Milano) - The results will compare loss in case of shake-map-aware re-provisioning strategies used for different time window. The results will show if it is worthy to have the shake map sooner than usual. (Sakarya Uni. and RISSC Lab.)	To investigate the necessity of early shake map generation.	Two or more journal papers, several conference paper.