STSM Report

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1 Action Number

CA15127 - Resilient Communication Services Protecting End-User Applications from Disaster-Based Failure.

2 STSM Title

Rain-Tolerant Wireless Mesh Network

3 STSM Applicant

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5 Period

03/12/2017 to 09/12/2017

6 Working group

Working Group 2: Weather-based disruptions

7 Purpose of the STSM

Wireless mesh networks formed by stationary nodes and high-capacity wireless links using directional antennas are a promising alternative to fibre-optic wired metropolitan area network as the fibre networks have high costs of deployment and maintenance.

However, due to the nature of wireless communications, wireless links are very susceptible to weather disruptions, and especially to rain storms resulting in signal attenuation. To overcome this, the next generation networks could be hybrid consisting of both optical-fibre links and wireless links. On one end optical-fibre link is more reliable than wireless link but the former is most expensive than the latter. Therefore, the goal is to explore hybrid network designs that are reliable in the presence of heavy rain fall and yet cost-effective. The purpose of the STSM is to:

- Define the requirements for designing a hybrid network consisting of wireless links and optical-fibre links which can be tailored to the technical requirements of the optical and wireless technologies such as the parameters for delay, reliability etc.
- Develop decision optimisation models and solution approaches using constraint programming for designing reliable and cost-effective hybrid networks.

8 Description of the Work Carried Out during STSM

The first task was to brainstorm and list the requirements, parameters, decisions, and constraints for designing cost-effective and reliable hybrid networks consisting of both optical-fibre links and wireless links.

Input Requirements.

- Location of Nodes.
- Demand Matrix point to point
- Number of gateways
- Probability of link failure for fibre connection and wireless connection (fibre-link failure is less likely than wireless link failure)
- Maximum number of wireless links incident to a node to avoid interference
- Capacity of each wireless link and fibre link
- Cost of a transponder, a fibre link and a wireless antenna (cost of wire link is more expense than cost of a wireless link)

Decisions.

- Decide which pairs of nodes are connected
- Decide whether the connection between a given pair of nodes is via fibre or wireless.
- Sizing of the network

- No. of antennas at each node
- No. of transponders at each node
- Number of fibres between a pair of nodes

Constraints/Objective

- Each node must be reachable to a gateway
- Each gateway node must have at least one incoming fibre link.
- The sub-graph restricted to the optical fibre links must also be connected.
- The network must satisfy the reliability threshold
- Reliability depends on the number of subgraphs connecting all the nodes
- Each demand must have a path in every subgraph
- Each subgraph must have sufficient transponders, antennas and fibres to satisfy all the demands
- Minimize cost - Depends on the number of antennas, transponders and the number of fibres

From the above set of the requirements it was clear that all these requirements cannot be considered while designing the network as the sizing of the network would depend on the routing of the demands. For designing the hybrid networks we selected subset of the requirements, constraints and decisions that are not related to sizing of the network.

We also discussed a reliability model for the hybrid network design, and developed an exact decision optimisation model. The definition of the problem is formalised and the decision optimisation models based on constraint programming model were also developed.

Encoding the reliability constraint in a decision optimisation model directly is difficult due to high level of of non-linearity. A lot of time was therefore spent on relaxation of the reliability constraint that can be incorporated in the decision optimisation.

9 Description of the results obtained

1. Formal definition of the hybrid network design problem
2. Mathematical formulation of the decision optimisation model using constraint programming
3. Two different ways of relaxing the reliability constraint
    - Explicitly encodes the inclusion/exclusion of the sub-graphs, the computation of the log-probabilities of the sub-graphs and uses the maximum log-probability times the number of sub-graphs for enforcing the relaxation of the reliability constraint.

- The second one discards the computation of the log-probabilities in the model, and simply computes the maximum log-probability of any sub-graphs prior to search based on which the relaxation of the reliability constraint is simply a lower bound on the number of sub-graphs included in the solution network.

10 Future collaboration and foreseen publications

The ongoing work is focusing on developing solution approaches for the previously mentioned models to efficiently compute cost-effective and reliable wireless fibre network (WiFi) designs.

The plan is to submit the results of this work in ONDM and/or RNDM 2018.