Reliable and Scalable Communication for the Power Grid

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Abstract. Future smart power grids require constant data availability for actuation of control decisions. The job of ensuring the timely arrival of data falls onto the network that connects these intelligent devices. This network needs to be fault tolerant. When nodes, devices or communication links fail along a default route of a message from A to B, the underlying hardware and software layers should ensure that this message will actually be delivered as long as alternative routes exist. Existence and discovery of multi-route pathways is essential in ensuring delivery of critical data.

In this work, we present methods of developing network topologies of smart devices that enable multi-route discovery in an intelligent power grid. This is accomplished through the utilization of software overlays that (1) maintain a digital structure for the physical network and (2) identify new routes in the case of faults. The resulting cyber network structure is scalable, reliable and inexpensive to build by extending existing infrastructure.

1 Introduction

Today’s critical infrastructure often governs control decisions of intelligent devices that can have a significant impact on human life, the environment and the economy. Ensuring that the appropriate data is available is crucial for making informed decisions. Such considerations are becoming increasingly important in cyber-physical systems (CPS) that combine computational decision making on the cyber side with...
physical control on the device side, let it be the power grid, medical devices or automotive subsystems.

Conventional embedded systems and a CPS differ in that the later governs physical devices through embedded control in a networked environment and has a direct impact on people who rely on such devices. Failure of network equipment in a CPS environment may have a number of impacts, such as

- faulty decisions regarding device malfunctioning,
- incorrect actuation (decisions) due to lack of data,
- system reconfigurations/restart, or
- severe performance degradation with missed deadlines.

In smart (power) grids that rely on commodity communication infrastructure, as one example, these types of failures are expensive and cause inefficiencies. Decisions are being made that affect the real world based on data passed within the network of smart grids. This impact on the real world makes it necessary to improve communication within the smart grid to ensure that the correct decisions are made in a timely manner.

Assuming correct device behavior, the timeliness requirement falls onto the network that connects these intelligent devices. Failures may occur in today’s CPS because of a lack of flexibility in routing decisions. Routing decisions are an important part of networking. Commodity networking equipment often relies on static routing techniques within networks. When there is a failure along a static route, any messages sent along that route will time out and result in communication failure. In these scenarios, many systems will assume points along this route to be out of service. This does not have to be the case.

Networks can be designed to be fault tolerant. When nodes, devices or communication links fail along a default route of a message from A to B, the underlying hardware and software layers should ensure that this message will actually be delivered as long as alternative routes exist. Networks of devices can be configured to contain multiple pathways to connect clusters of nodes in a redundant manner. One can ensure delivery of critical data via different network routes, i.e., multi-route pathways need to exist. A network, upon discovery of a faulty route, then needs to be able to utilize an alternate route.

In conventional networks, the main objective is to maximize throughput. Commodity network equipment is designed to provide high levels of throughput. This design choice runs counter to the needs of an intelligent distributed network required for next-generation CPS infrastructure. For example, in a power grid, the guarantee that a message is delivered is more important than high rates of throughput. Sample tasks the power grid must perform, such as distributed load balancing [4], substantiate this need. Thus, system components need to collaborate intelligently upon a component network failure to accommodate sustained communication needs at all times.

Network failures may conventionally result in message delivery failure. This can be avoided through smart routing technologies that can bypass faulty equipment in modern network topologies. However, such fault tolerance is only feasible in