Composable Ethernet Communication Architecture for Complex Real-Time Applications

Motivation

Cyber-Physical Systems (CPS), which may be briefly described as systems in which computers converge with the physical world, are typically based on distributed architectures in which several intelligent nodes communicate over a digital network to accomplish a common goal. The complexity of CPS has been growing steeply, due to both increases in size and functionality, and is becoming a major development concern. For instance, unmanaged complexity is currently one of the most challenging problems in automotive electronics development.

This situation is pushing paradigm changes in the methodologies used in the design of complex CPS. Component-oriented design methodologies, exhibiting the composability property, i.e., the capability of integrating diverse components in a system in which they share resources while satisfying their individual service requirements and enforcing mutual temporal isolation, are considered an effective means to tackle the growing complexity of CPS. Server-oriented architectures are an effective means to enable such kind of resource sharing, and can be the basis for resource partitioning and virtualization, supporting the separation between application components as well as between the application software and the hardware platform on which they will execute. Such separation has the potential to bring significant cost reductions at the system level and is currently the object of active frameworks such as AUTOSAR in the automotive domain, IMA in avionics or IEC61499 in industrial automation.

Many CPS are distributed and have real-time requirements. In those cases, suitable real-time networks must be used to interconnect the nodes and provide timely message delivery. However, currently available real-time communication protocols do not allow efficient server-based scheduling policies as those developed for CPU scheduling. Even when available, network partitions are typically static, as in TDMA-based approaches, and do not adapt to variations in number of active components in the system or in their requirements. Moreover, the respect for network partitions is frequently delegated to the end nodes that must execute a specific layer on top of the general network interface, typically a traffic shaper, which is a limitation for the integration of legacy systems and other general purpose systems that do not originally include such layer. Finally, even in the cases in which such layer can be effectively deployed, the proper operation of the system requires the compliance of all system components to a achieve a correct temporal behavior.

Objectives

This PhD research plan proposal addresses the limitations of current real-time network technologies, above identified. The research work will focus on real-time Ethernet (RTE) communication protocols, that are becoming the *de facto* standard in many industrial domains.

The research work to be carried out departs from an implementation of the the FTT-SE framework on a costumized Ethernet switch, currently under development under the scope of the FCT HaRTES project (PTDC/EEA-ACR/73307/2006), extending it with server scheduling capabilities.

The following specific objectives will be addressed:

- Related-work survey:
  - Study of server-class services present in COTS switches, and
  - Study and characterization of RTE protocols (TTE, ProfiNET, ...)
- Development of server-based scheduling mechanisms to the FTT-SE switch
- Development of schedulability analysis techniques
- Development of dynamic reconfiguration algorithms and related reconfiguration protocols
- Investigation and assessment of multi-switch architectures
- Investigation and development of fault-tolerance mechanisms

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