Real-Time USB Communication in the Quest Operating System

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Motivations
- CAN bus style, high bandwidth, interconnect for distributed embedded systems
- Future cyber-physical applications

Objectives
- Predictable data stream processing from different devices, e.g. different cameras
- QoS guarantees on communication channels sharing physical network links

Applications
- Automotive systems
- Avionics
- Robotics
- Cyber-physical systems

Main Contributions
- Guarantee bandwidth allocations when opening connections with communication endpoints
- Dynamically reorder transfer requests to avoid unnecessary rejections along with a USB scheduling algorithm that outperforms implementations such as those found in Linux
- Provide real-time guarantees for both asynchronous and periodic transfers

USB Scheduling Problem
- Given a set of tuples: \((w_1, t_1), (w_2, t_2), \ldots, (w_n, t_n)\)
- \(w_i\) - time to send transaction \(i\), depends on packet size and type of transaction
- \(t_i\) - interval of transaction \(i\), can either be: 1, 2, 4, 8, 16, 32, ..., 1024
- Transactions cannot cross micro-frame (125µs) boundaries
- Given a set of tuples is there an assignment such that all transactions obey their interval and do not cross micro-frame boundaries
- Quest heuristic: sort \(t_i\) by smallest to largest breaking ties using largest \(w_i\) first

Experimental Evaluation

<table>
<thead>
<tr>
<th>Request</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time in Microframe (µs)</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Reordering Point</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 1: Bandwidth Allocation Results

<table>
<thead>
<tr>
<th>OS</th>
<th>Tokens Passed Without Third Beagleboard</th>
<th>Tokens Passed With Third Beagleboard</th>
<th>Third Beagleboard Isoc Endpoints Opened</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quest</td>
<td>1499</td>
<td>1499</td>
<td>5</td>
</tr>
<tr>
<td>Linux</td>
<td>1499</td>
<td>360</td>
<td>7</td>
</tr>
</tbody>
</table>

References