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Google ProjectARA Power Management Challenges

About the Power Management of a Modular Platform

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Introduction

- Smartphones only available in one-size-fits-all configurations.
- Google ProjectAra redefining that by creating a Linux-based platform where consumers may assemble the device they like from just the modular components they need.
- Providing such flexibility comes with many power management challenges
  - Modular components are separate from the "main" phone, hotpluggable.
  - Platform power consumption cannot be pre-characterized/optimized
- New ways must be designed to incorporate management of their power into the existing Android/Linux infrastructure.
  - "How do we do runtime power management of a module?"
  - "How do we ensure there's enough power to supply to a module added dynamically?"
  - "How do we protect the platform from malfunctioning modules ?"
  - "How we balance modules communication bus power / performances ?"
  - ...

Menu of the Day

- ProjectARA basics
- High-Level ProjectARA Power Management Architecture
- ProjectARA Power Management Challenges & Solutions
  - Module Runtime Power Management
  - Unipro Link Power Management
  - Module Idle Power Management
  - Module Power Allocation
  - Module Over-consumption Protection
  - Module Thermal Management
- Q & A

Scope

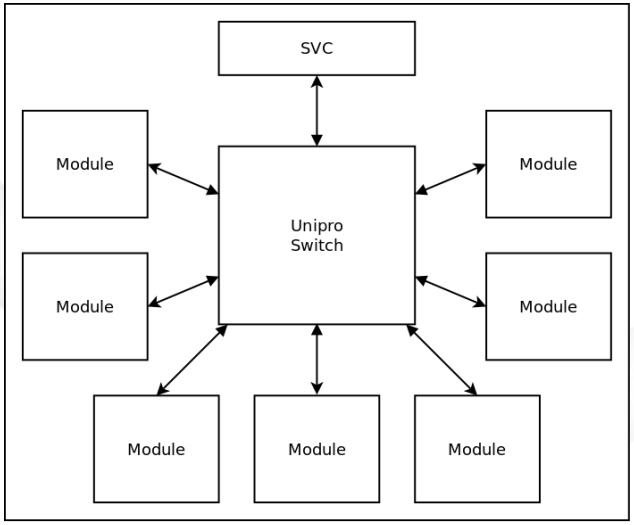
- Includes
  - How to optimize the power consumption of the Ara subsystem, including
    - The Ara modules,
    - The Supervisory Controller (SVC),
    - The UniPro network (Switch, Bridges).
- Excludes
  - Application Processor (SoC) power management
    - Identical to regular Android smartphones.
  - Battery Management

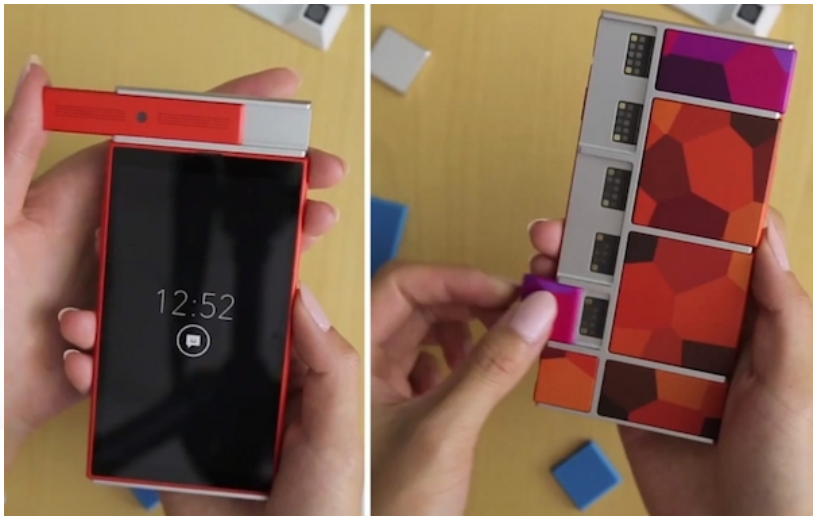
ProjectARA Basics

Technologies, terminology, ...

What is ProjectARA ?

- A modular device platform that:
  - Acts as a phone, but supports add-on modules
  - Detects module insertion and controls module removal
  - Manages power to modules independently
  - Provides a UniPro network, balancing power and performances
  - Uses a manifest to describe module capabilities
  - Leverages online sources to support modules if required





Unipro

- High-speed interface technology for interconnecting integrated circuits in mobile electronics
  - Bidirectional multi-lane links, up to 5 Gbps per lane
- Low-power (links can run at lower data rates to reduce power consumption)
- Designed for low pin count, small silicon area, data reliability and robustness
- Used in ProjectAra to interconnect modules
- https://en.wikipedia.org/wiki/UniPro

Greybus

- Designed for ProjectAra to abstract communication with Modules
- Defines messages sent over connections between modules
- Supports “operations” that pair a request and response message
- Protocols define sets of operations a connection supports
- Protocols implement classes of device behavior
- Modules advertise classes they support in a "manifest"
- https://github.com/projectara/greybus-spec
- https://github.com/projectara/greybus

Endoskeleton

- Rigid substrate, but as lightweight as possible
- Physical guides hold modules in place
- Electrically controlled mechanism prevents removal
- Slots available in several module sizes (1x1, 1x2, 2x2)
- Each slot has an electrical “interface block”

Figure 2.1 - Ara Endo (Medium Variant)

Supervisory Controller (SVC)

- Part of the EndoSkeleton
- Module maintenance
  - Insertion/Removal,
  - Power control,
  - Power monitoring
- Unipro Network Management
  - Switch Control
  - Connection Establishment

Modules

- Different sizes : 1x1, 1x2, 2x2
- Implements 1 or more feature(s)
  - Camera, Speaker, Sensor(s), ...
  - 'Bundle' as per Greybus terminology
- May have 1 or 2 interface block(s)
  - 1x1, 1x2 modules : 1 interface block
  - 2x2 modules : 2 interface blocks
  - 'Interface' as per Greybus terminology
- Includes a Unipro Bridge chip
- Runs NuttX RTOS

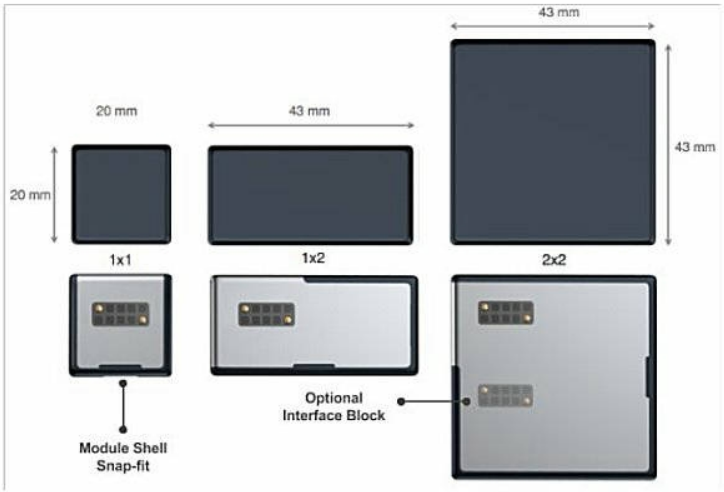
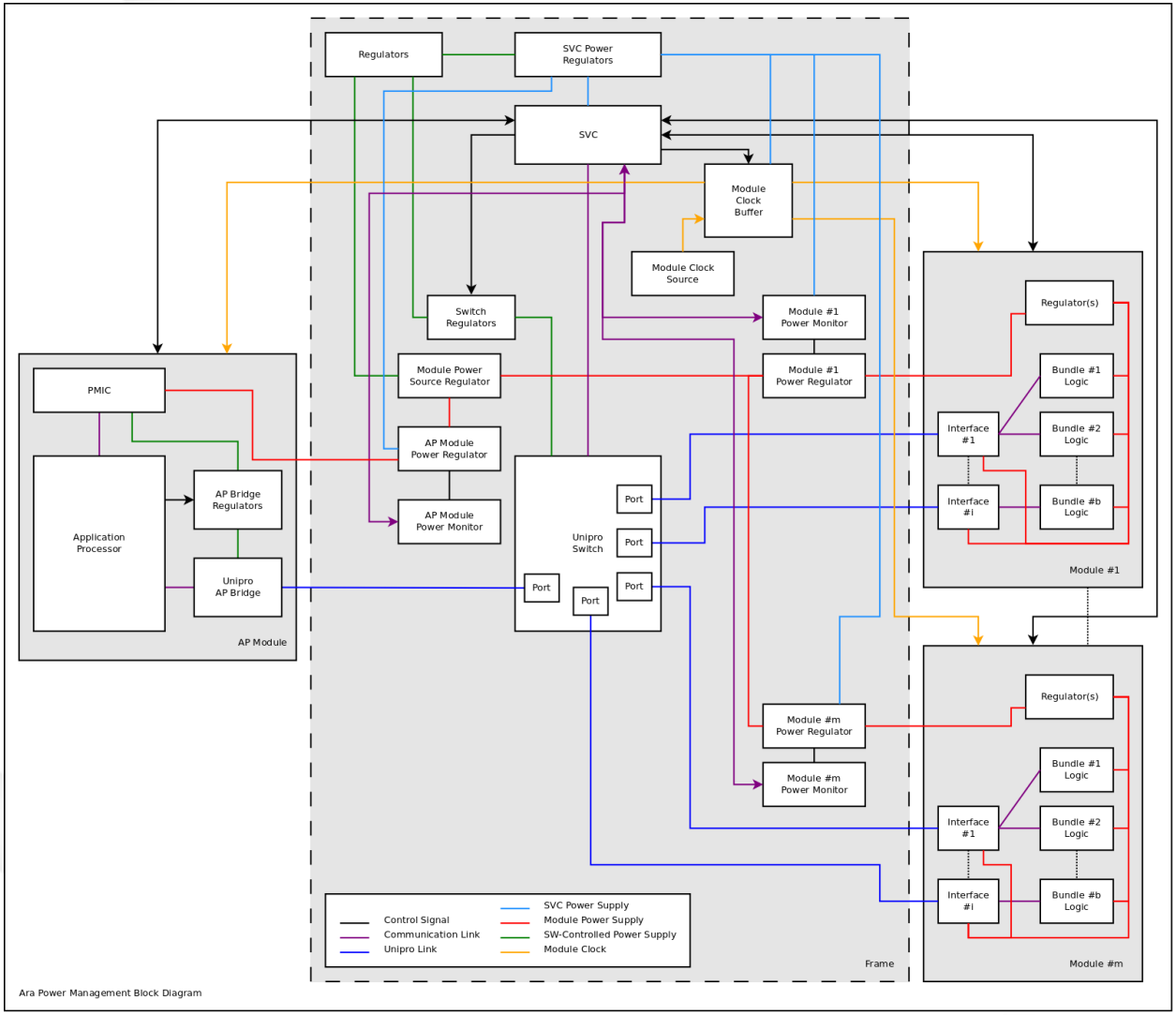


Figure 2.5 - Rear Modules

High-Level ProjectARA Power Management Architecture

Ara Power Management Architecture



Ara Power Management Block Diagram

ProjectARA Power Management

Challenges & Solutions

Module Runtime Power Management (1)

- Dynamically power ON/OFF/Suspend a given module, depending on its usage.
  - ON state: module required to execute the active use-case(s),
  - OFF state:module not required to execute any active use-case,
  - SUSPEND state: module not required to execute the current use-case(s) but
    - Module’s state shall be maintained,
    - Power OFF transition latency not matching performance requirements.
- Always driven by use-case (power transitions happen at use-case boundaries only),
- Always initiated by the Application Processor, never by the module.
- Modules Greybus Drivers integrate the standard Linux RuntimePM callbacks
- Leverages dynamic driver loading capability of Linux Kernel

Module Runtime Power Management (2)

- Available：
  - Linux RuntimePM Framework
  - Linux Dynamic Driver Loading

- To Be Done:
  - Greybus RuntimePM Operations
  - Greybus Interface & Bundle Power States
  - Greybus Interface & Bundle Power State Transitions & Dependencies
  - Greybus Interface & Bundle Driver RuntimePM callbacks
  - SVC support for Greybus RuntimePM Operations
  - Module FW support for Greybus RuntimePM Operations

Module Power Allocation (1)

- To protect the Ara platform from brownout
- Make sure that at any time, platform has enough power available to :
  - Supply a new module,
  - Supply a new processing on a module,
  - Eject a module
- Policy aggregating power allocation requests from Greybus drivers
  - Running on AP
  - Constantly monitoring the battery level
    - Power budget decreasing with battery level
- SVC monitors allocated power budget not exceeded by modules.
  - HW-shutdown of faulty modules

Module Power Allocation (2)

- Existing :
  - Nothing

- To be done:
  - Power Allocation Framework
  - Greybus Module Power Allocation Operations
  - SVC Power Monitoring/Limitation Support
  - Module Power Consumption Characterization
  - Module Power Consumption Profiling
  - Policy (incl. optimization)

Module Over Consumption Protection (1)

- To protect platform from module(s) that may draw more power than allowed
- Shut down module power source ASAP.
  - HW-driven, no SW involved.
- Leverage always-on power monitoring devices
- Leveraged by Module Power Allocation FWK
  - Dynamically adjusting module max power limit

Module Over Consumption Protection (2)

- Existing :
  - Nothing
- To be done :
  - SVC FW Power Monitoring support
    - Nuttx driver for Power Monitoring Chips
    - Power Monitoring FWK
  - Greybus Power Monitoring operations
  - Integration with Module Power Allocation FWK

Module Idle Power Management (1)

- To Minimize the power consumption of a module while it is not doing any processing, but required by an active use-case.
  - Transitions a module (interface(s) / bundle(s)) into a low-power state between two processing tasks.
  - From RuntimePM perspective, module remains in ON power state.
- May include clock gating, clock and voltage scaling, power switching
  - Depending on module architecture and capabilities.
- Managed by module FW, without awareness of the Application Processor (AP) kernel (Greybus driver).

Module Idle Power Management (2)

- Available :
  - Module RTOS (NuttX) Power Management Framework
- To be done:
  - Module Idle States
  - NuttX Power Management Framework callbacks
  - Module Idle Power Consumption Optimization

SVC Idle Power Management

- Similar to Module Idle Power Management
- Reduce the SVC power consumption while it is not processing any greybus operation or event.
  - SVC Idle 99% of the time
- May include clock gating, clock and voltage scaling, power switching.
- SVC still able to detect any new events/requests, even in a lowest power state.
- Driven locally by the SVC itself, without awareness of the Application Processor (AP) kernel.

Unipro Link Power Management (1)

- Dynamic scaling of UniPro link “power mode”, depending on
  - Active system use-case performance requirements,
  - Module data movement profiles
    - Latency-bound, bandwidth-bound, jitter tolerance, ...
    - E.g. Speaker module more sensitive to latency than bandwidth jitter
- Includes heuristic(s), aggregating Unipro performance requests issued by module drivers and other system policies
  - E.g. also used for Thermal Management
- Managed by AP kernel and SVC FW only, modules not involved
- Shall not degrade user experience.

Unipro Link Power Management (2)

- Existing :
  - Nothing
- To be done :
  - Unipro Link Power Management FWK
  - Greybus Link Power Management operation
  - Greybus Bundle Driver integration
  - SVC Link Power Management support
  - Module data movement profiling
  - Heuristics (incl. optimization)

Unipro Switch Power Management (1)

- To dynamically reduce the power consumption of the UniPro Switch depending on UniPro network configuration,
  - Gating unused UniPro ports,
  - Hibernating the device when the Ara platform is suspended,
  - Powering down the device when the phone powers down.
- May include clock gating, clock and voltage scaling, unipro hibernation.
- Driven by the SVC solely, without awareness of the Application Processor (AP) kernel.

Unipro Switch Power Management (2)

- Existing :
  - Nothing
- To be done :
  - SVC FW Support for Switch Power Management

Thermal Management (1)

- Mounted on the back of the phone, modules shall not warm too much and harm user
- Model frame and modules as thermal zones
  - Modules may include thermal sensor
- Model Unipro Links and modules as cooling devices
  - Dynamic scaling of Unipro Links Power Mode (speed)
  - Dynamic power switching of modules
- Modules may include local thermal management
  - FW driven, without kernel awareness
- Leverages the Linux Kernel standard Thermal Management FWK

Thermal Management (2)

- Existing :
  - Linux Thermal Management Framework
- To be done :
  - Greybus Thermal Management operations
  - Module FW Thermal Management support
  - Integration with Linux Thermal Management FWK
  - Integration with Unipro Link Power Management FWK
  - Thermal Policy optimization

Q & A

Thank you!