Improving Energy Efficiency of Wireless Communication Circuitry in Miscellaneous Electric Loads

Performing Organization(s): University of Virginia, University of Michigan, ORNL
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Project Summary

Timeline:

Start date: January 1, 2018

Planned end date: December 31, 2020

Key Milestones

1. Complete WiFi wakeup receiver and node controller IC design; 12/31/18
2. Measured IC results and application to MELs; 802.15.4 wakeup; 12/31/19
3. Integrated system reducing MELs phantom energy by 50%; 12/31/20

Budget:

Total Project $ to Date:

- DOE: $872,598
- Cost Share: $88,067

Total Project $:

- DOE: $2,639,999
- Cost Share: $266,667

Key Partners:

U. Michigan	ORNL
Samsung	Trane
UTRC	Johnson Controls
SkyCentrics	PsiKick

Project Outcome:

Develop a Connectivity Module to reduce MELs phantom energy by over 50% and idle energy by over 20%.

This module leverages custom integrated circuits for wakeup from WiFi at <1 mW and wakeup from 802.15.4 at < 500 µW.

Team

University of Virginia			U. Michigan	ORNL
				
Dr. Ben Calhoun	Dr. Brad Campbell	Dr. Kamin Whitehouse	Dr. David Wentzloff	Dr. Teja Kuruganti

MELs Power State Management

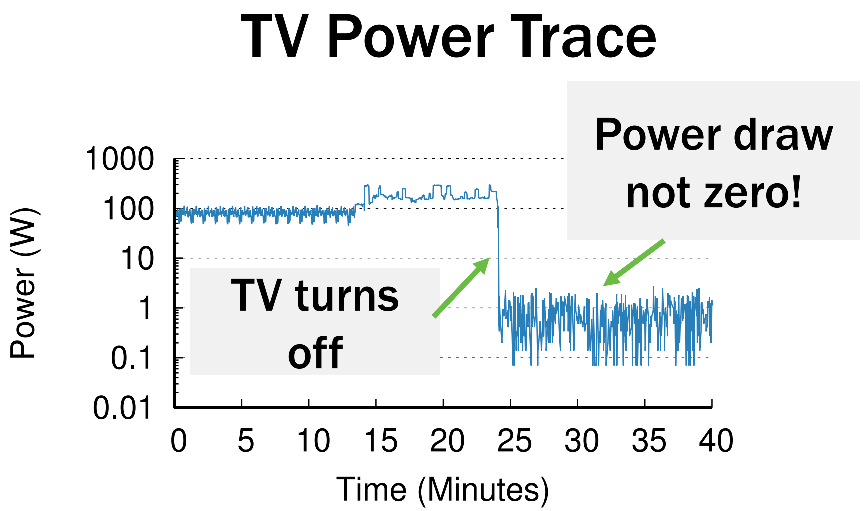
Network and Integration

Custom Integrated Circuits

Cross-hierarchical team to address MELs connectivity and efficiency

Challenge

Many miscellaneous electric loads (MELs) consume phantom power when off simply to enable connectivity or to remain in standby mode. This small, yet continuous, power draw (typically 1-3 Watts) adds up, costing upwards of $30/year/home.



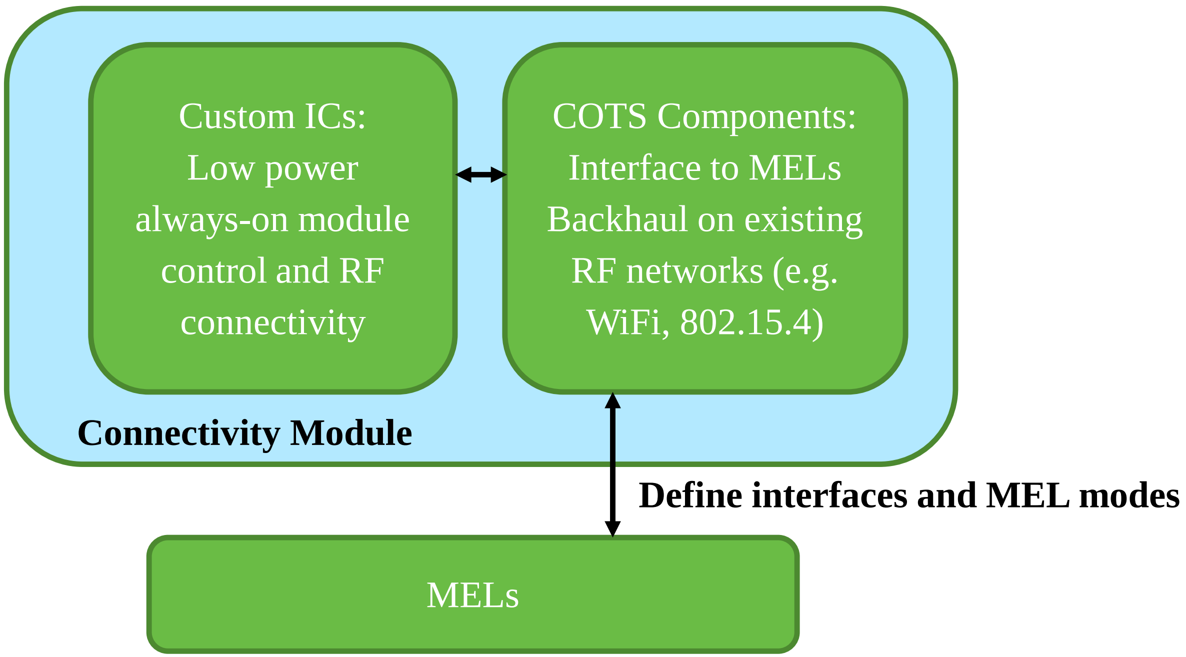
Ideally, when a MEL is switched off it would consume zero power.

At a national scale MELs are…

- 30% of electricity in residential buildings
- 36% of electricity in commercial buildings

We propose leveraging advances in ultra-low-power wireless radios and smart control methods to cut phantom power consumption of MELs by 60-90%.

Approach



- Custom radio frequency (RF) wakeup receiver (WRX) ICs for WiFi and 802.15.4
- Custom ICs for MELs interfacing and continuous control
- Custom printed circuit board (PCB) for integration into Connectivity Module
- Wake on Wireless (WoW) capability
- MELs WoW and control optimization

Impact

- Demonstrate prototype WiFi wakeup receiver with < 1 mW active power
- Demonstrate prototype 802.15.4 wakeup receiver with < 500 µW active power
- Demonstrate custom integration IC with <50 µW active power
- Prototype Connectivity Module and integrate with appliances
- Lower MELs phantom energy by over 50%
- Lower MELs idle energy by over 20%

Progress

- Specification for WiFi wakeup receiver (WRX) complete
- Specification for custom integration IC complete
- Integration plan for appliances complete

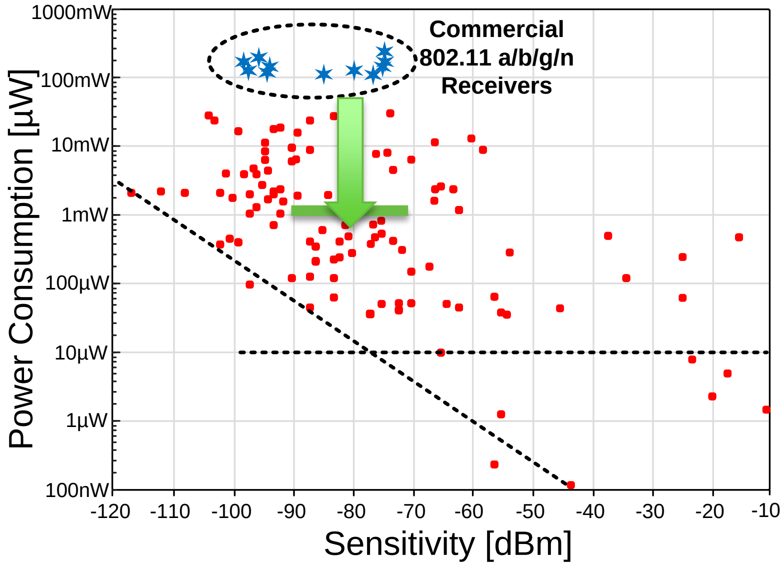
BP1 Project Scope: Development Objectives

1. Design and demonstrate in simulation a WiFi WRX at <1mW active power.
2. Design and demonstrate in simulation a custom node controller IC that can interface with the WiFi WRX at <50μW active power (excluding radios).
3. Demonstrate in simulation that WiFi wakeup protocols are viable and can be integrated into existing networking protocols.
4. Show using simulation and modeling that integrating wakeup functionality can reduce the average power of MELs radios by at least 50%.

Motivation for Wakeup Radios

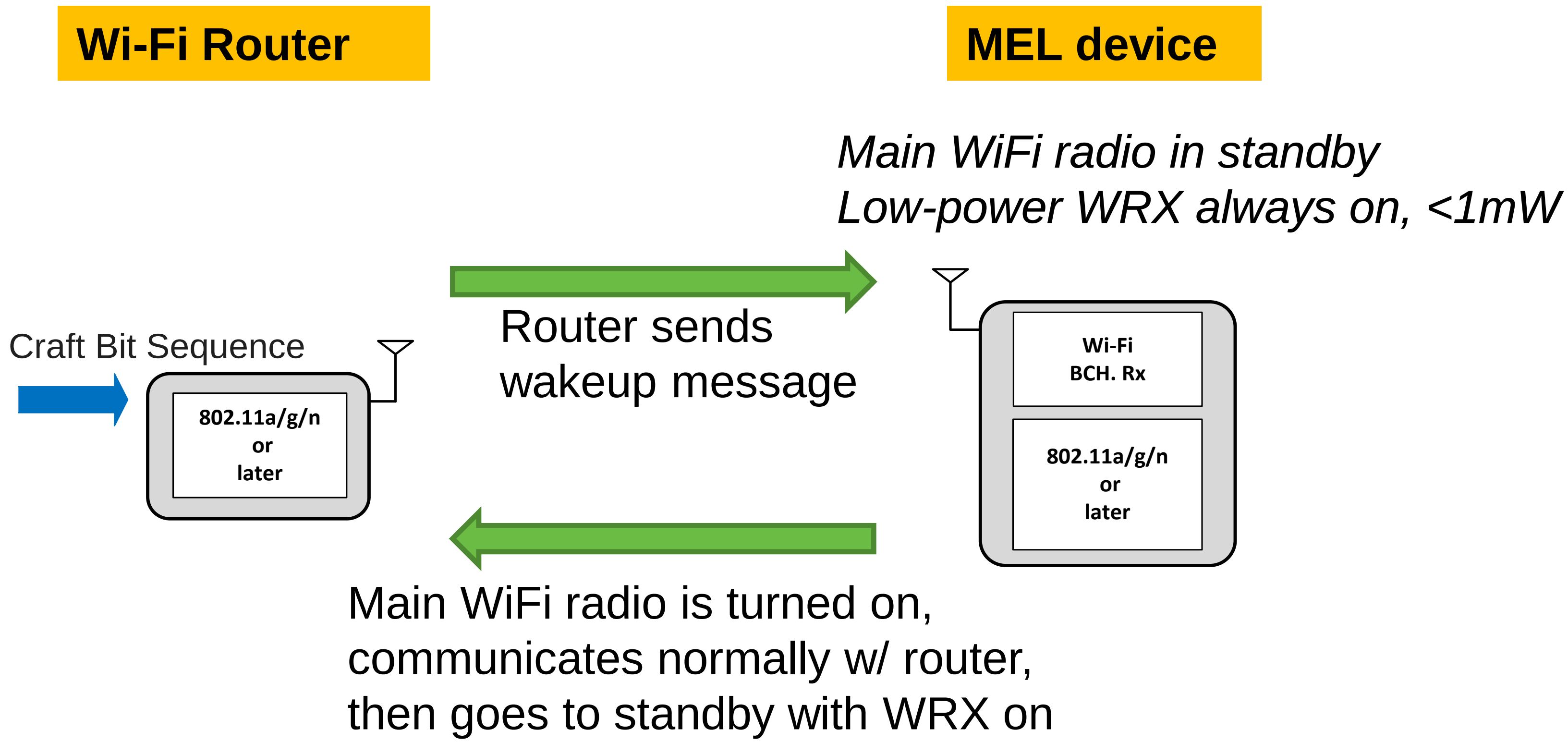
- WiFi radios consume >100mW when active, with high average power to stay connected to a network
- Low power receivers are not compliant with any standard
- Objective: develop low power wakeup radio that is compatible with the WiFi standard

State-of-art ULP radio survey from 2005 to 2017



Networking Plan Leveraging Wakeup Radios

- Use "always-on" WiFi router to wakeup MEL device
- Average power of MEL device = WRX radio power (<1mW)

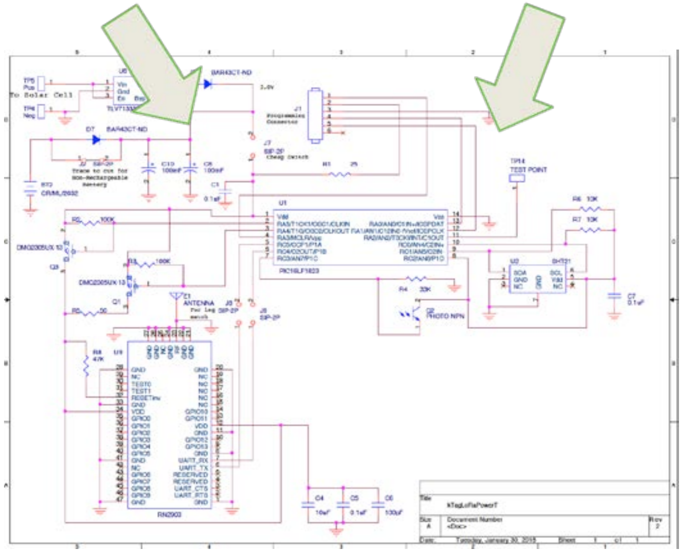


Approach for MELs Interfacing

- **Connectivity Module Architecture design**
  - Interface WRX IC to Building Automation systems (BAS)
- **Integration Plan: Two key metrics**
  - Persistent connectivity (100% availability)
  - Architecture demonstration for Wi-Fi-enabled devices
- **Reference Architecture**
  - GERBER files and layout specification
  - Demonstrate Interoperability

Requirement specification of WRX/WoW

MELs and BAS Interoperability requirements



Reference Architecture Demonstrates Interoperability with MELs and BAS

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Node Controller Plan

- **Motivation: WRX requires support during standby; COTS processors are ~mW when active**

- **Needs for Node Controller IC:**
  - Power delivery and power management
  - Clocking
  - WRX configuration, control, baseband
  - Interfacing with COTS (WiFi, MELs, etc.)

- **Approach:**
  - Leverage existing platforms
  - Expect new work emphasizing the WRX and Interfaces

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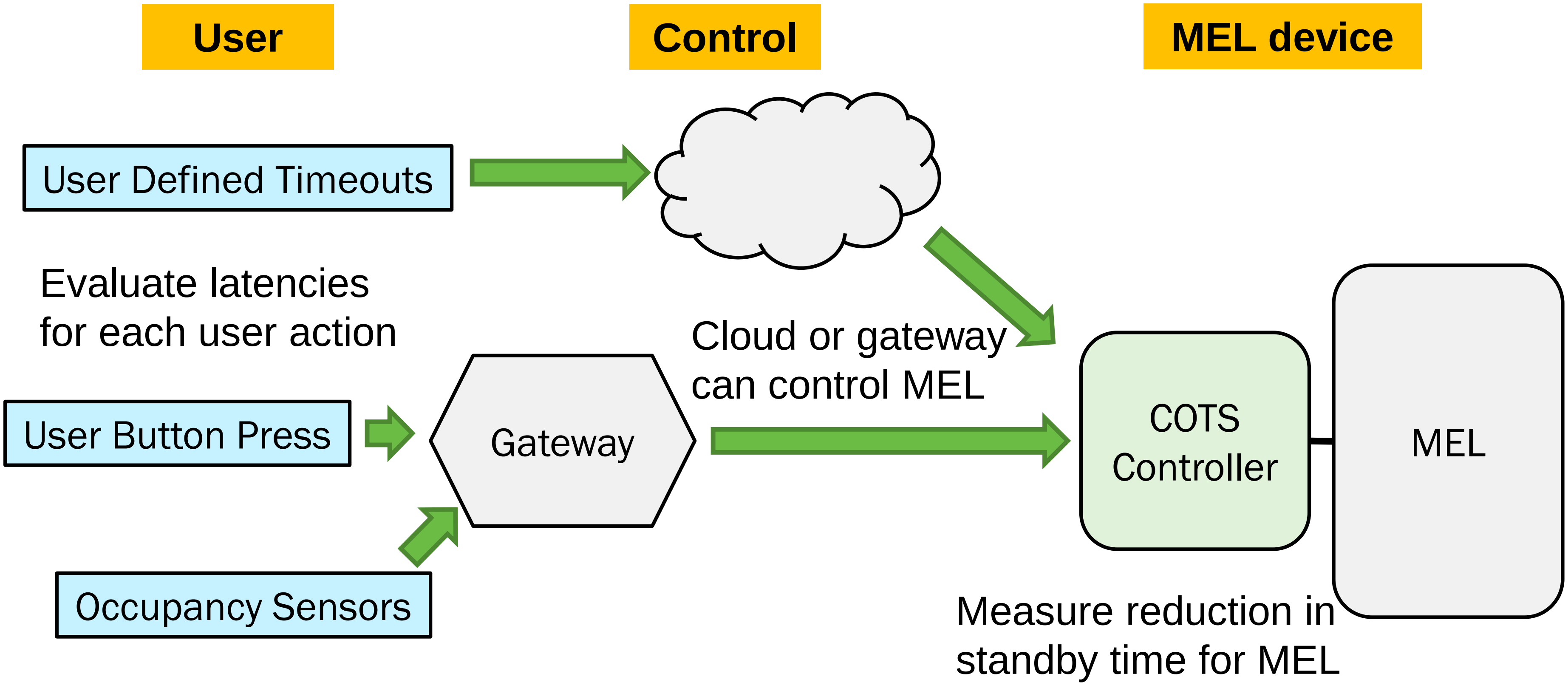
Evaluating User Acceptance of Reactive Control

- Control loads based on timers, occupancy, or remote control.
- Show potential phantom power reductions based on these control modes.



Stakeholder Engagement

- **Multi-institutional Team with Complementary Strengths:**
  - U. Virginia: Low power IC control, MELs control
  - U. Michigan: Low power RF Ics
  - ORNL: MELs interface platforms

- **Broader Stakeholder Engagement:**
  - Learn about technology needs
  - Coordinate on interfacing requirements
  - Optimize for increased impact

Thank You

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REFERENCE SLIDES

Project Budget

Project Budget: $2,906,666
Variances: No variances to date
Cost to Date: Exact Q1 expenditures not available at ppt submission time
Additional Funding: N/A

Budget History					
1/1/18 – FY 2017 (past)		FY 2018 (current)		FY 2019 – FY 2020 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
NA	NA	$872,598	$88,067	$1,767,401	$178,601

Project Plan and Schedule

- Project dates: 1/1/18 to 12/31/20 – currently on original schedule
- Schedule and Milestones: on schedule - see SOPO and PMP for details
- No milestone slips to date
- No past Go/no-go decisions; next Go/no-go decision point is 12/31/18
- Current and future work: see SOPO and PMP for details

Project Schedule - RELEVANT HIGHLIGHTS												
Project Start: 1/1/18		Completed Work										
Projected End: 12/31/20		Active Task (in progress work)										
		Milestone/Deliverable (Originally Planned)										
SUMMARY: ON SCHEDULE		Milestone/Deliverable (Actual)										
	CY2018				CY2019				CY2020			
Task	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work												
Q1 Milestones: chip specs, MELs power mgt prototype												
Current/Future Work												
Q2 Milestones: see SOPO for details												
Q3 Milestones: see SOPO for details												