IoTivity-Constrained: IoT for tiny devices

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Overview

- Introduction
- Background in OCF
- Constrained environment characteristics
- IoTivity-Constrained architecture
- Porting IoTivity-Constrained
- Building Applications

Introduction

- Open Connectivity Foundation (OCF)
  - Publish open IoT standards
- IoTivity-Constrained
  - Small foot-print implementation of OCF standards
  - Runs on resource-constrained devices and small OSes
  - Quickly customize to any platform

OCF standards

A brief background

OCF resource model

- RESTful design: Things modeled as resources with properties and methods
- CRUDN operations on resources (GET / OBSERVE, POST, PUT, DELETE)
- OCF roles
  - Server role: Exposes hosted resources
  - Client role: Accesses resources on a server

OCF “well-known” resources

Functionality	Fixed URI
Discovery	/oic/res
Device	/oic/d
Platform	/oic/p
Security	/oic/sec/*
…	…

Refer to the OCF Core spec at https://openconnectivity.org/resources/specifications

OCF protocols

- Messaging protocol: CoAP (RFC 7252)
- Data model: CBOR (RFC 7049) encoding of OCF payloads
- Security model: DTLS-based authentication, encryption and access control*
- Transport: UDP/IP; being adapted to Bluetooth

*Refer to the OCF Security spec at https://openconnectivity.org/resources/specifications

Resource discovery

Multicast GET coap://224.0.1.187:5683/oic/res

Unicast response

[URI: /a/light; rt = [“oic.r.light”], if = [“oic.if.rw”],
p= discoverable, observable]

GET and PUT requests

Unicast GET coap://192.168.1.1:9000/a/light

Unicast response

[URI: /a/light; state = 0, dim = 0]

Unicast PUT coap://192.168.1.1:9000/a/light
PayLoad: [state=1;dim=50]

Unicast response

Status = Success

OBSERVE and Notify

Unicast GET coap://192.168.1.1:9000/a/light; Observe_option= 0

Unicast response

[URI: /a/light; state = 1, dim = 50]

Notify Observers

[URI: /a/light; state = 0, dim = 0, sequence #: 1]

Constrained environment characteristics

Constrained device classes

- RFC 7228

Name	Data size (e.g., RAM)	Code size (e.g., Flash)
~~Class 0, C0~~	~~<< 10 KiB~~	~~<< 100 KiB~~
Class 1, C1	~ 10 KiB	~ 100 KiB
Class 2, C2	~ 50 KiB	~ 250 KiB

Must accommodate (at a minimum) OS + Network stack + drivers + IoTivity-Constrained application

Hardware

- Low RAM and flash capacity
- Low power CPU with low clock cycle
- Battery powered devices

Software

- Lightweight OS
- No dynamic memory allocation
- Many options (OS, network stack, …) -> API fragmentation
- Execution context design and scheduling strategy

IoTivity-Constrained features

- OCF roles, resource model, methods, data model, protocol and flows
- CoAP Block-wise transfers (RFC 7959)
  - Application pre-configures MTU size for specific device / deployment
  - Reduce buffer allocations in the network and link layers
- OCF security model
  - Onboarding, provisioning and access control*

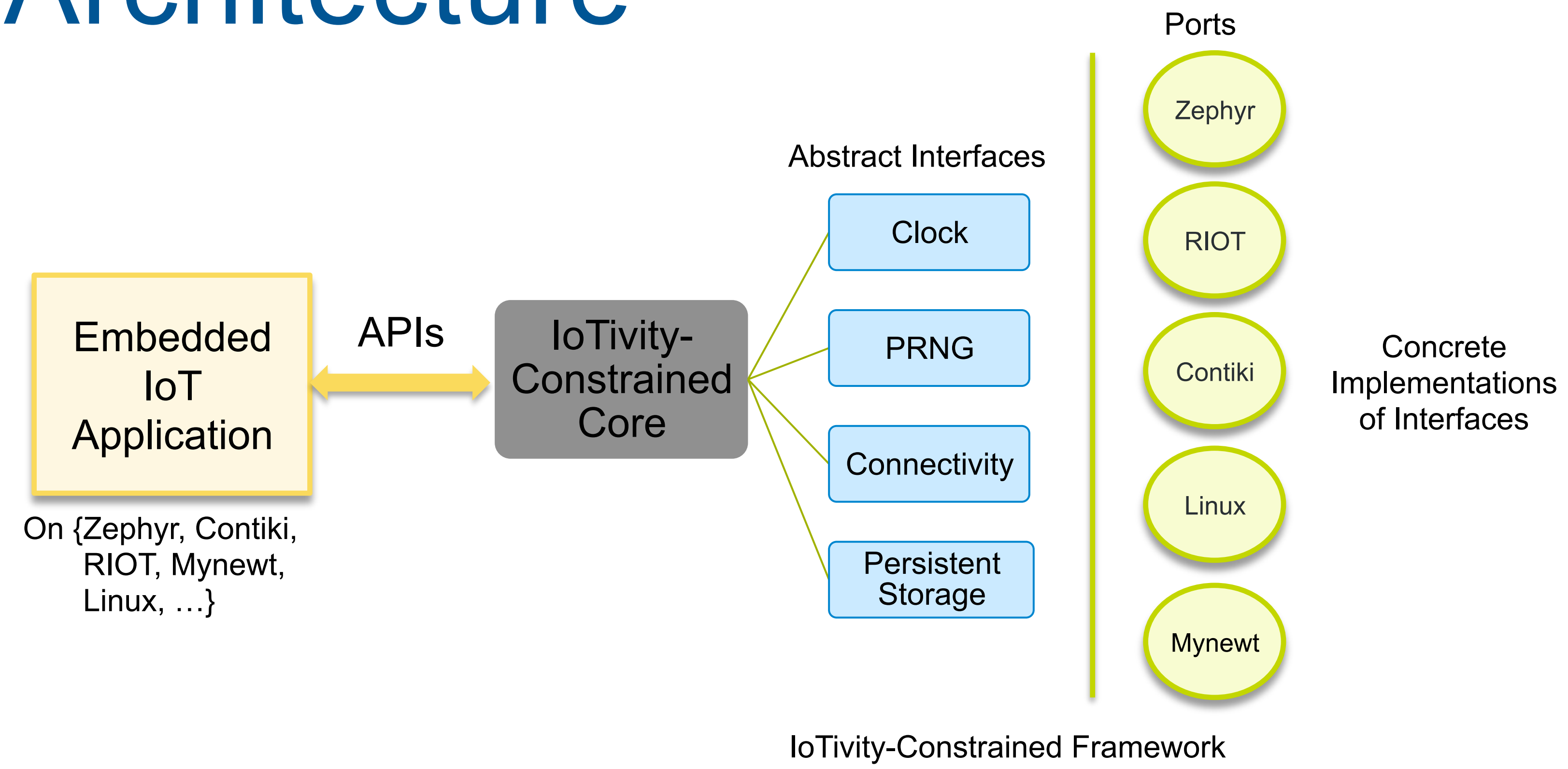
*Refer to the OCF Security spec at https://openconnectivity.org/resources/specifications

IoTivity-Constrained architecture

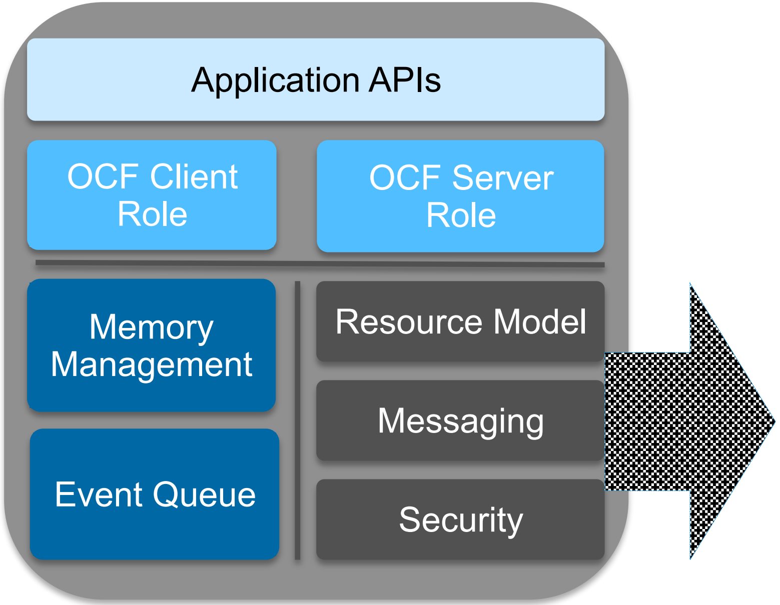
Architectural goals

- OS-agnostic core
- Abstract interfaces to platform functionality
- Rapid porting to new environments
- Static memory allocation
- Modular and configurable

Architecture

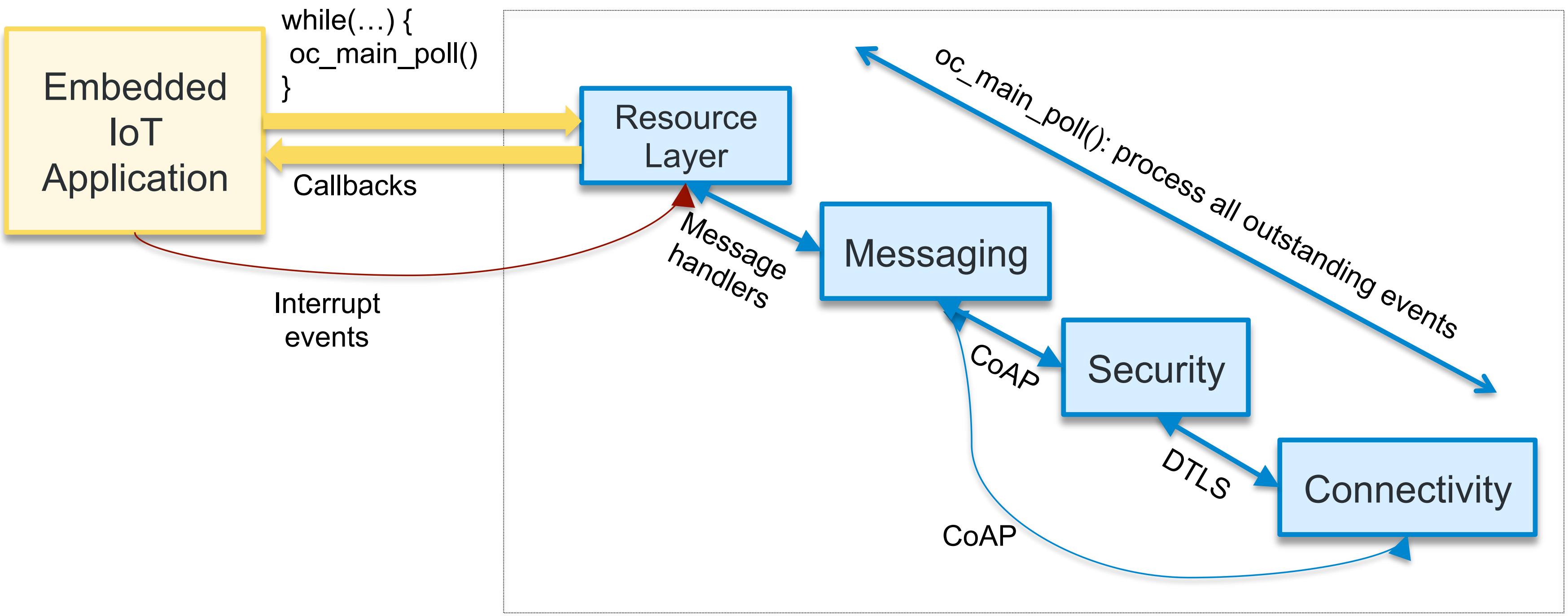


Core block



Interact uniformly with Interface implementations for all ports

Event loop execution

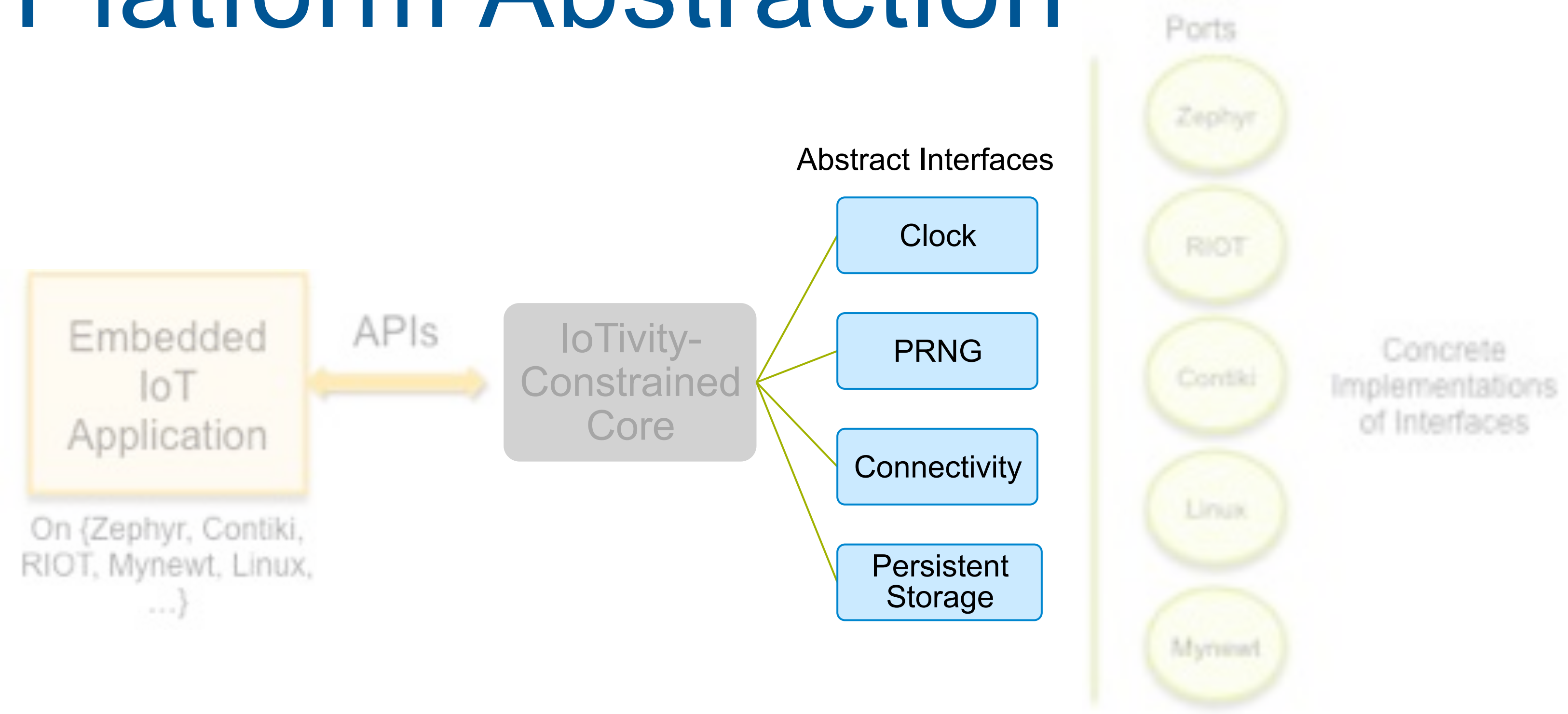


Idle mode and signaling

```
...
// Initialize a semaphore
while (1) {
    oc_clock_time_t next_event = oc_main_poll();
      // next_event is the absolute time of the next scheduled
      // event in clock ticks. Meanwhile, do other tasks
      // or sleep (e.g., wait on semaphore)
...
// Framework invokes a callback when there is new work
static void signal_event_loop(void) {
    // Wake up the event loop (e.g., signal the semaphore)
}
```

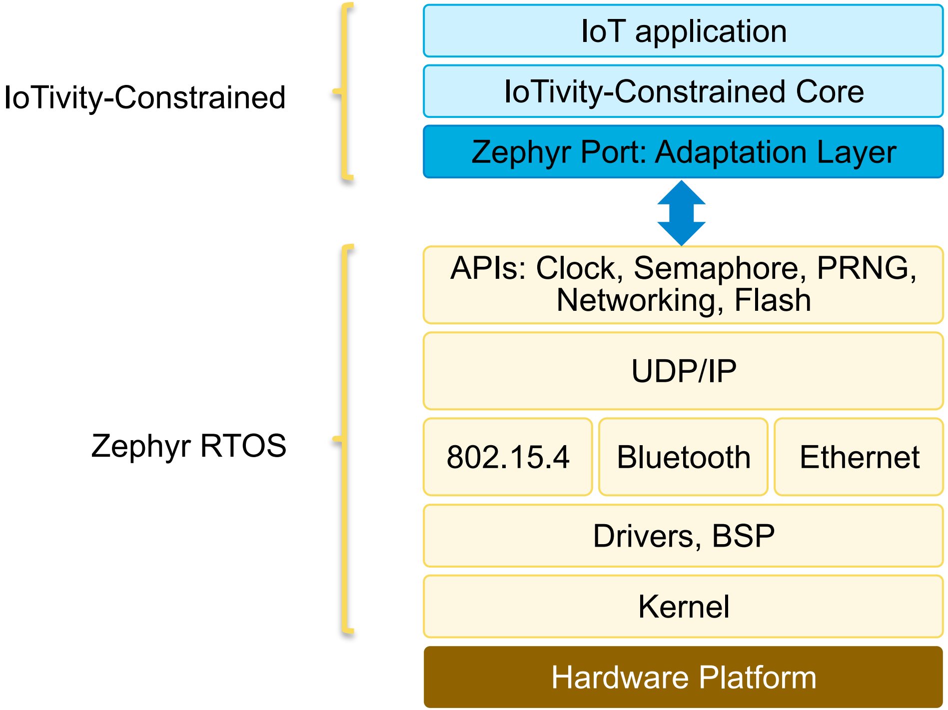
Porting IoTivity-Constrained

Platform Abstraction



IoTivity-Constrained Framework

Zephyr adaptation



Clock

```
// Set clock resolution in IoTivity-Constrained's configuration
// file: config.h
#define OC_CLOCK_CONF_TICKS_PER_SECOND (...)
typedef uint64_t oc_clock_time_t; // timestamp field width

// Declared in port/oc_clock.h
// Implement the following functions using the platform/OS's
// APIs, For eg. on Linux
// using clock_gettime()
void oc_clock_init(void);
oc_clock_time_t oc_clock_time(void);
```

Connectivity

```
// Declared in port/oc_connectivity.h
// Implement the following functions using the platform's
// network stack.
int oc_connectivity_init(void);
void oc_connectivity_shutdown(void);
void oc_send_buffer(oc_message_t *message);
void oc_send_discovery_request(oc_message_t *message);
uint16_t oc_connectivity_get_dtls_port(void);
```

- oc_message_t contains remote endpoint information (IP/Bluetooth address), and a data buffer

Connectivity events

- Capture incoming messages by polling or with blocking wait in a separate context and construct an oc_message_t object
- Message injected into framework for processing via oc_network_event()
- Based on nature of OS or implementation, might require synchronization

```
void oc_network_event_handler_mutex_init(void);
void oc_network_event_handler_mutex_lock(void);
void oc_network_event_handler_mutex_unlock(void);
```

PRNG

```
// Declared in port/oc_random.h
// Implement the following functions to interact with the
// platform's PRNG
void oc_random_init(void);
unsigned int oc_random_value(void);
void oc_random_destroy(void);
```

Persistent storage

```
// Declared in port/oc_storage.h
// Implement the following functions to interact with the
// platform's persistent storage
// oc_storage_read/write must implement access to a key-value store
int oc_storage_config(const char *store_ref);
long oc_storage_read(const char *key, uint8_t *buf, size_t size);
long oc_storage_write(const char *key, uint8_t *buf, size_t size);
```

Building Applications

Application structure

- Implemented in a set of callbacks
  - Initialization (Client / Server)
  - Defining and registering resources (Server)
  - Resource handlers for all supported methods (Server)
  - Response handlers for all requests (Client)
  - Entry point for issuing requests (Client)
- Run event loop in background task
- Framework configuration at build-time (config.h)

Background task in application

```
main() {
  static const oc_handler_t handler = {.init = app_init,
                                       .signal_event_loop =
                                        signal_event_loop,
                                       .register_resources =
                                        register_resources };
...
  oc_main_init(&handler);
...
  while (1) {
    oc_clock_time_t next_event = oc_main_poll();
...
```

Initialization

```
void app_init(void) {
  oc_init_platform("Intel", NULL, NULL);
  oc_add_device("/oic/d", "oic.d.light", "Lamp", "1.0",
                "1.0", NULL, NULL);
}
```

- Populate standard OCF resources (platform / device)

Defining a resource

```
....
void register_resources(void) {
  oc_resource_t *res = oc_new_resource("/a/light", 1, 0);
  oc_resource_bind_resource_type(res, "core.light");
  oc_resource_bind_resource_interface(res, OC_IF_R);
  oc_resource_set_default_interface(res, OC_IF_R);
  oc_resource_set_discoverable(res, true);
  oc_resource_set_observable(res, true);
  oc_resource_set_request_handler(res, OC_GET, get_light, NULL);
  oc_add_resource(res);
}
```

Resource handler

```
....
bool light_state;
int brightness;
....
static void get_light(oc_request_t *request,
                      oc_interface_mask_t interface, ...) {
  // Call oc_get_query_value() to access any uri-query
  oc_rep_start_root_object();
  oc_rep_set_boolean(root, state, light_state);
  oc_rep_set_int(root, brightness_level, brightness);
  oc_rep_end_root_object();
  oc_send_response(request, OC_STATUS_OK);
}
```

Resource discovery

```
oc_do_ip_discovery("oic.r.light", &discovery, NULL);
....
oc_server_handle_t light_server;
char light_uri[64];
...
oc_discovery_flags_t discovery(..., const char *uri, ...,
                               oc_server_handle_t *server,
                               ,...) {
  strncpy(light_uri, uri, strlen(uri));
  memcpy(&light_server, server, sizeof(oc_server_handle_t));
  return OC_STOP_DISCOVERY;
  // return OC_CONTINUE_DISCOVERY to review other resources
}
```

Issuing a request

```
// Populated in the discovery callback
oc_server_handle_t light_server;
char light_uri[64];
...
oc_do_get(light_uri, &light_server, "unit=cd", &get_light,
          LOW_QOS, NULL);
...
```

Response handler

```
void get_light(oc_client_response_t *data) {
  oc_rep_t *rep = data->payload;
  while (rep != NULL) {
    // rep->name contains the key of the key-value pair
    switch (rep->type) {
    case BOOL:
      light_state = rep->value_boolean; break;
    case INT:
      brightness = rep->value_int; break;
    }
    rep = rep->next;
  }
}
```

Framework configuration

- Set at build-time in a file config.h
  - Number of resources
  - Number of payload buffers and maximum payload size
  - Memory pool sizes
  - MTU size (for block-wise transfers)
  - Number of of DTLS peers
  - DTLS connection timeout
  - …

Project configuration

- `make [BOARD=<type>] menuconfig`
  - **Stack size for main thread**
  - Network stack options
    - **IPv6, UDP**, 6LoWPAN, 6LoWPAN_IPHC
    - **Number of network contexts (sockets)**
    - **Number of network RX/TX buffers, data size**
    - Bluetooth host options: L2CAP CoC, GATT, master/slave modes
    - **Layer 2 options:** IEEE 802.15.4, Bluetooth LE, Ethernet
  - **PRNG implementation**

IPv6 over BLE (IPSP) support

- Transport UDP/IPv6 over BLE L2CAP (RFC 7668)
- Build 6LN with IPv6, 6Lo_IPHC, BT peripheral mode and L2CAP CoC
- Use sample IPSS for connection setup
- Supported on Arduino 101*
- Test communication with Linux (>= 3.16) as master/central

* https://www.zephyrproject.org/doc/boards/x86/arduino_101/doc/board.html#arduino-101

Conclusion

Summary and plans

- Growing interest from community and prospective OCF vendors
- OCF standards compliance; participate in OCF Plugfest
- Motivate definition of constrained device profile in OCF spec
- Investigate special requirements of industrial and healthcare verticals
- Addition of independent, higher-level components

- **We welcome your contributions!**

Questions?

Source code: https://gerrit.iotivity.org/gerrit/gitweb?p=iotivity-constrained.git

IoTivity mailing list: iotivity-dev@lists.iotivity.org

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