ObjectFlow for Microcontrollers

Simple and Reliable Data Flow Graph programming for embedded applications

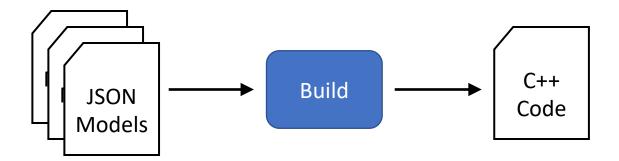
ObjectFlow

- Data-driven programming for tiny microcontrollers
- Arduino Uno class (2KB/32KB) and larger
- Small library, no central executive, timer- and communication event-driven
- Similar to IEC61499, Node-RED, etc. based on Data Flow Graphs (DFG)
- Uses the LWM2M data model and semantics with an event-driven communication protocol
- Communication is implemented in the application layer using a set of well-known LWM2M types

ObjectFlow - Digital Twin for Embedded Code

- On-device code is simple, minimal, and reliable
- A small set of primitives implemented as static C++ wrapper classes for Object and Resource
- Graphs are build from a standardized JSON format that models Object and Resource Instances on the embedded device – a digital twin of the device code
- Tools construct a C++ header file template that is built with the device code application handler bundle using the standard IDE (e.g. Arduino IDE), and downloaded to the device in the usual way.

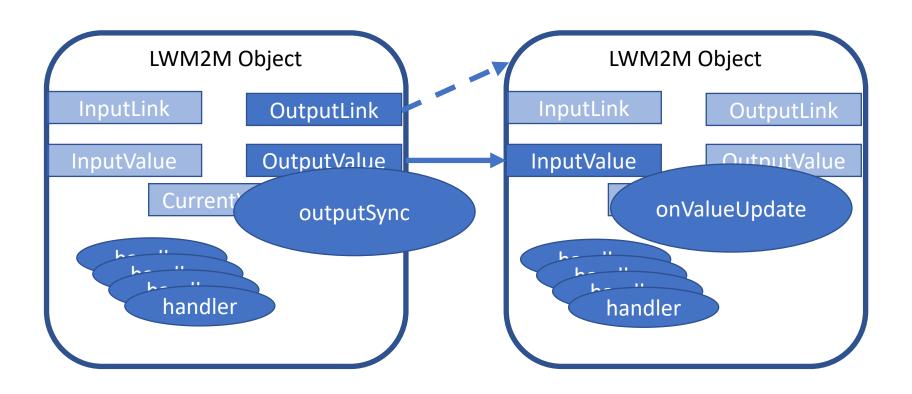
High Level Process



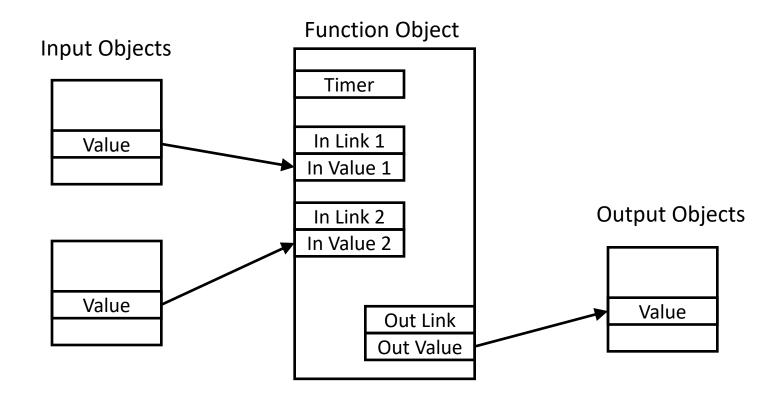
ObjectFlow – DFG wrapper

- A small set of Resource types for communication
 - Time types for Current, Interval, and LastActivation
 - Input and Output link types based on LWM2M Objlink
 - Subtypes for Input, Output, and Current Value
- DFG communication is event driven and initiated according to application logic
 - Bound methods implement application handlers
 - InputSync (data pull) and OutputSync (data push)
 - onValueUpdate, onValueSync, onInterval handlers

ObjectFlow – DFG and Reactive Communication



Complex Function Objects



ObjectFlow – DFG architecture

- An ObjectFlow application is a Data Flow Graph
- DFG Nodes are implemented as LWM2M Objects
- A DFG Node is a collection of one or more Objects
- LWM2M Object Links (Objlink) are used to group Objects into a DFG Node and to implement the data flow connections between Nodes (arcs, edges)

Example graph

TimeSource: Type: TimeSource IntervalTime: 1000 TimerOutputLink: AnalogInput AnalogInput: Type: AnalogInput GpioPinID: 7 IntervalTime: 0 OutputLink: MapToCelsius MapToCelsius: Type: ValueMap InputLowScale: InputHighScale: 1023 CurrentLowScale: 0 CurrentHighScale: 100 CurrentValueMinimum: 0 CurrentValueMaximum: 100 CurrentValueUnit: C OutputLink: Display Display: Type: Publisher InputValue: { ValueType: IntegerType }

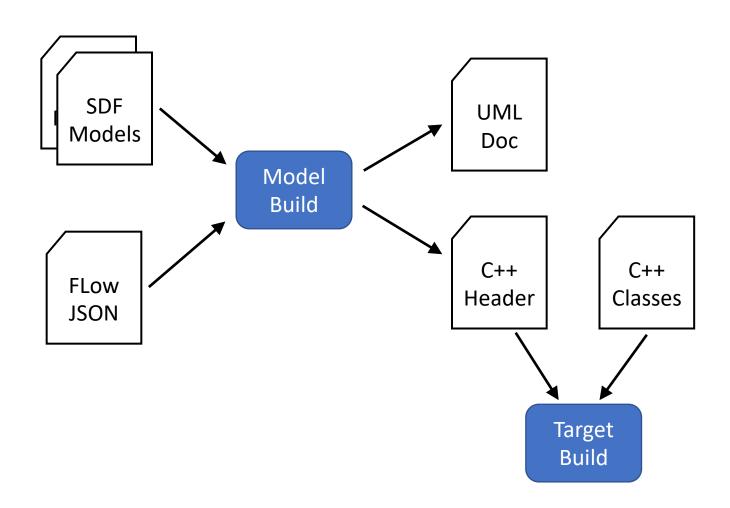
TimeSource Type: TimeSource IntervalTime: 1000 OutputLink: AnalogInput AnalogInput Type: AnalogInput IntervalTime: 0 GpoiPinID: 7 OutputLink: ScaleMapper MapToCelsius Type: ValueMap InputLowScale: 0 InputHighScale: 1023 CurrentLowScale: 0 CurrentHighScale: 100 CurrentValueMinimum: 0 CurrentValueMaximum: 100 CurrentValueUnit: C OutputLink: Display Display Type: Publisher

InputValue: { ValueType: IntegerType }

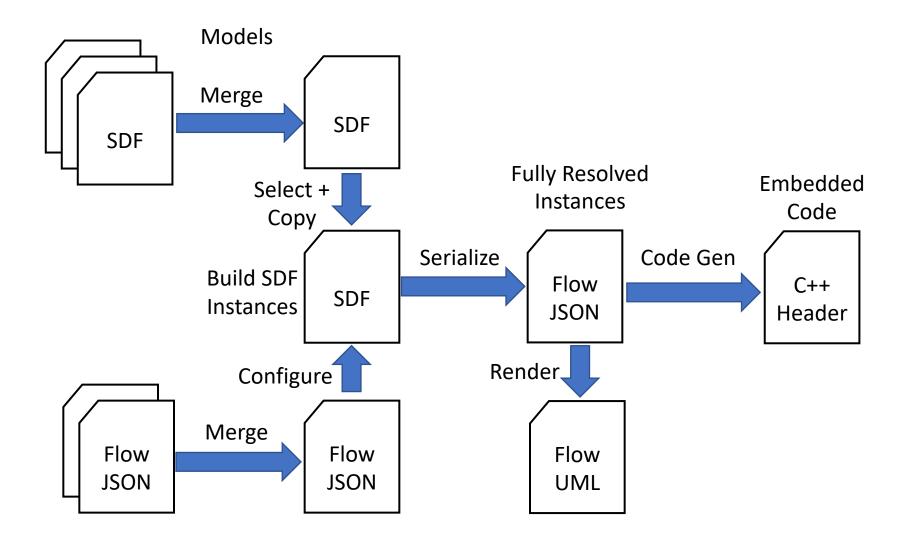
ObjectFlow - Tools

- The DFG model tools do all of the heavy lifting so the embedded code can be extremely simple and lightweight, e.g. type checking is done in the model
- Code generation involves serialization of the objects and resources into a C++ header file, and packaging of the implementation code for the application objects (time and data event handlers)
- The result is a standard C++ package that can be built by any C++ toolchain (Arduino, etc.)

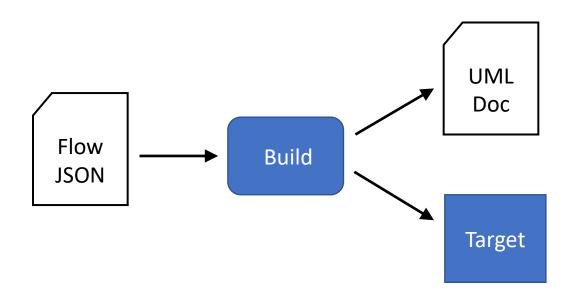
High Level Process



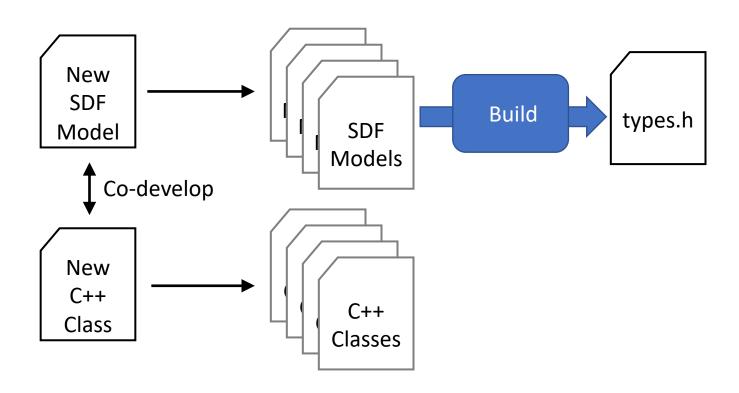
Build Process



Making a New Flow Graph



Making a New Object



Example SDF Model

```
defaultnamespace: objectflow
sdfData:
  # add this ObjectType ID to the TypeID registry
  TypeID:
    ObjectType:
      Publisher: { const: 43008 }
sdfThing:
  # Publisher Object
  Publisher:
    sdfRef: /#/sdfThing/ObjectFlowObject
    sdfData:
      TypeID:
                                                        => TypeID: { const: 43008 }
        sdfRef: /#/sdfData/TypeID/ObjectType/Publisher
    # Publisher Object Resources
    sdfRequired:
      - /#/sdfThing/Publisher/sdfThing/InputValue
    sdfThing:
      InputValue:
        sdfRef: /#/sdfThing/ObjectFlowObject/sdfThing/InputValue
        ValueType:
          sdfChoice:
            default: { sdfRef: /#/sdfData/ValueType/sdfChoice/IntegerType }
    sdfAction:
      OnDefaultValueUpdate: Publish the data to the endpoint
```

```
defaultnamespace: objectflow
                                   Example SDF Instance
sdfThing:
 # Instance Graph
  InstanceGraph:
    sdfRef: /#/sdfThing/ObjectList
   # Objects in the graph
    sdfThing:
      TimeSource:
        sdfRef: /#/sdfThing/TimeSource
        sdfThing:
         IntervalTime:
           sdfProperty:
             Value:
               sdfChoice:
                 IntegerType: { const: 1000 }
         OutputLink:
           sdfData:
             SdfLink:
{ InstancePointer: /#/sdfThing/InstanceGraph/sdfThing/AnalogInput }
     AnalogInput:
        sdfRef: /#/sdfThing/AnalogInput
        sdfThing:
         GpioPinID:
           sdfProperty:
             Value:
               sdfChoice:
                 IntegerType: { const: 7 }
           OutputLink:
             sdfData:
               SdfLink:
```

{ InstancePointer: /#/sdfThing/InstanceGraph/sdfThing/ScaleMapper }

```
defaultnamespace: objectflow
                                                 Simplified DSL
sdfThing:
 # Instance Graph
                                                   TimeSource:
  InstanceGraph:
   sdfRef: /#/sdfThing/ObjectList
                                                     Type: TimeSource
   # Objects in the graph
                                                     IntervalTime: 1000
   sdfThing:
                                                     TimerOutputLink: AnalogInput
      TimeSource:
                                                   AnalogInput:
       sdfRef: /#/sdfThing/TimeSource
       sdfThing:
                                                     Type: AnalogInput
         IntervalTime:
                                                     GpioPinID: 7
           sdfProperty:
                                                     OutputLink: MapToCelsius
             Value:
               sdfChoice:
                 IntegerType: { const: 1000 }
         TimerOutputLink:
           sdfData:
             SdfLink:
 InstancePointer: /#/sdfThing/InstanceGraph/sdfThing/AnalogInput }
     AnalogInput:
       sdfRef: /#/sdfThing/AnalogInput
       sdfThing:
         GpioPinID:
           sdfProperty:
             Value:
               sdfChoice:
                 IntegerType: { const: 7 }
           OutputLink:
             sdfData:
               SdfLink:
{ InstancePointer: /#/sdfThing/InstanceGraph/sdfThing/MapToCelsius }
```

Reserved LWM2M Types

TypeID:

```
ResourceType:
InputLinkType: { const: 27000 }
OutputLinkType: { const: 27001 }
InputValueType: { const: 27002 }
CurrentValueType: { const: 27003 }
OutputValueType: { const: 27004 }
CurrentTimeType: { const: 27005 }
IntervalTimeType: { const: 27006 }
LastActivationTimeType: { const: 27007 }
```

```
#define InputLinkType 27000
#define OutputLinkType 27001
#define InputValueType 27002
#define CurrentValueType 27003
#define OutputValueType 27004
#define CurrentTimeType 27005
#define IntervalTimeType 27006
#define LastActivationTimeType 27007
```

Resolved Instance Graph

