ObjectFlow for Microcontrollers

Simple and Reliable Data Flow Graph programming for embedded applications

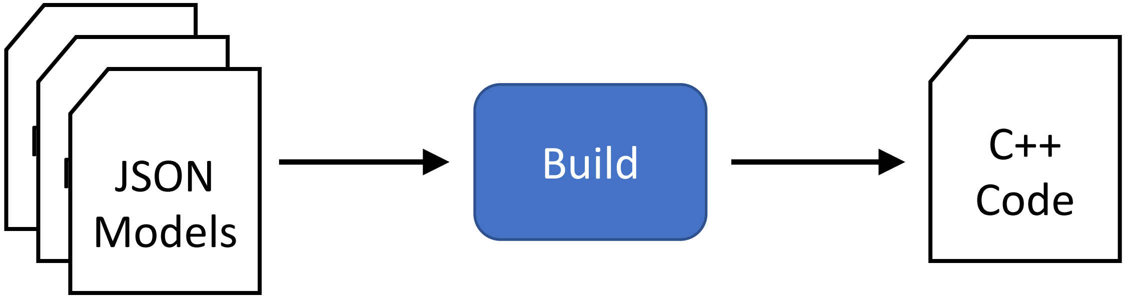
ObjectFlow

- 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.

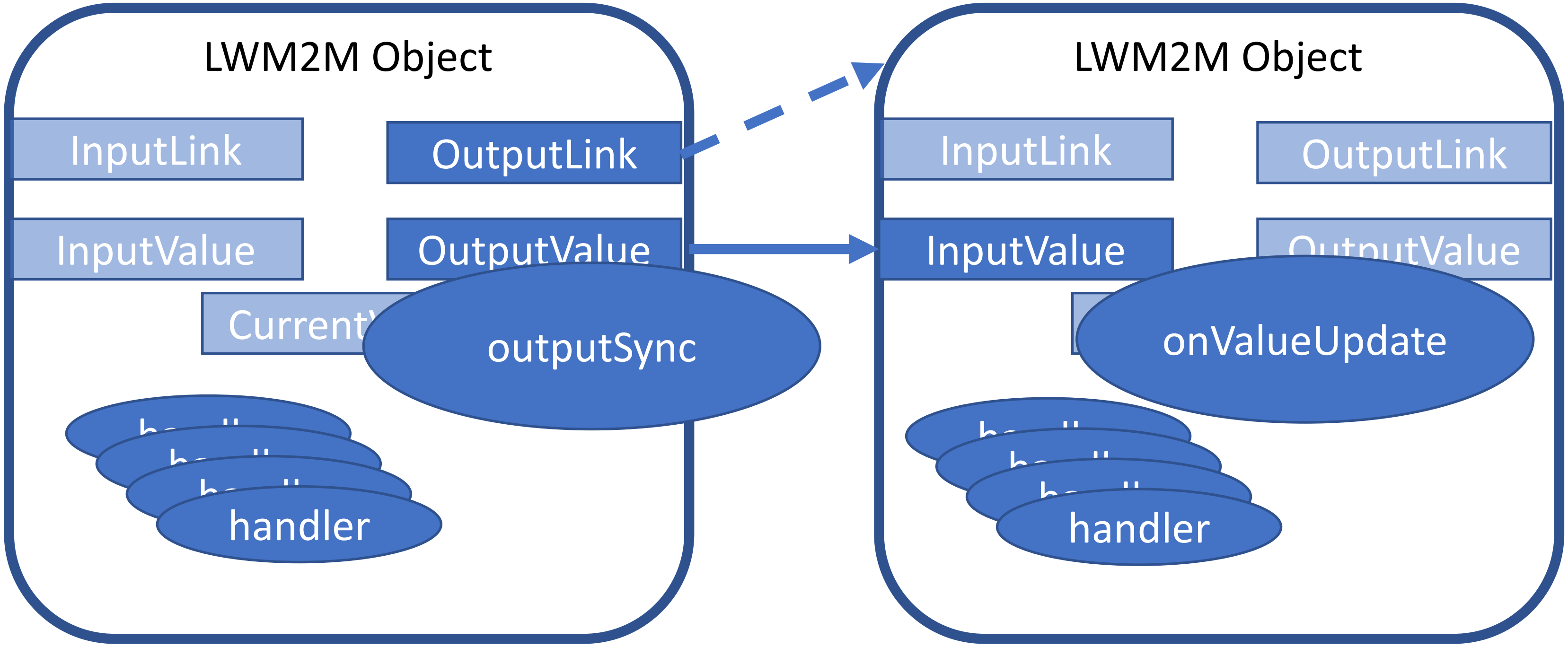
High Level Process



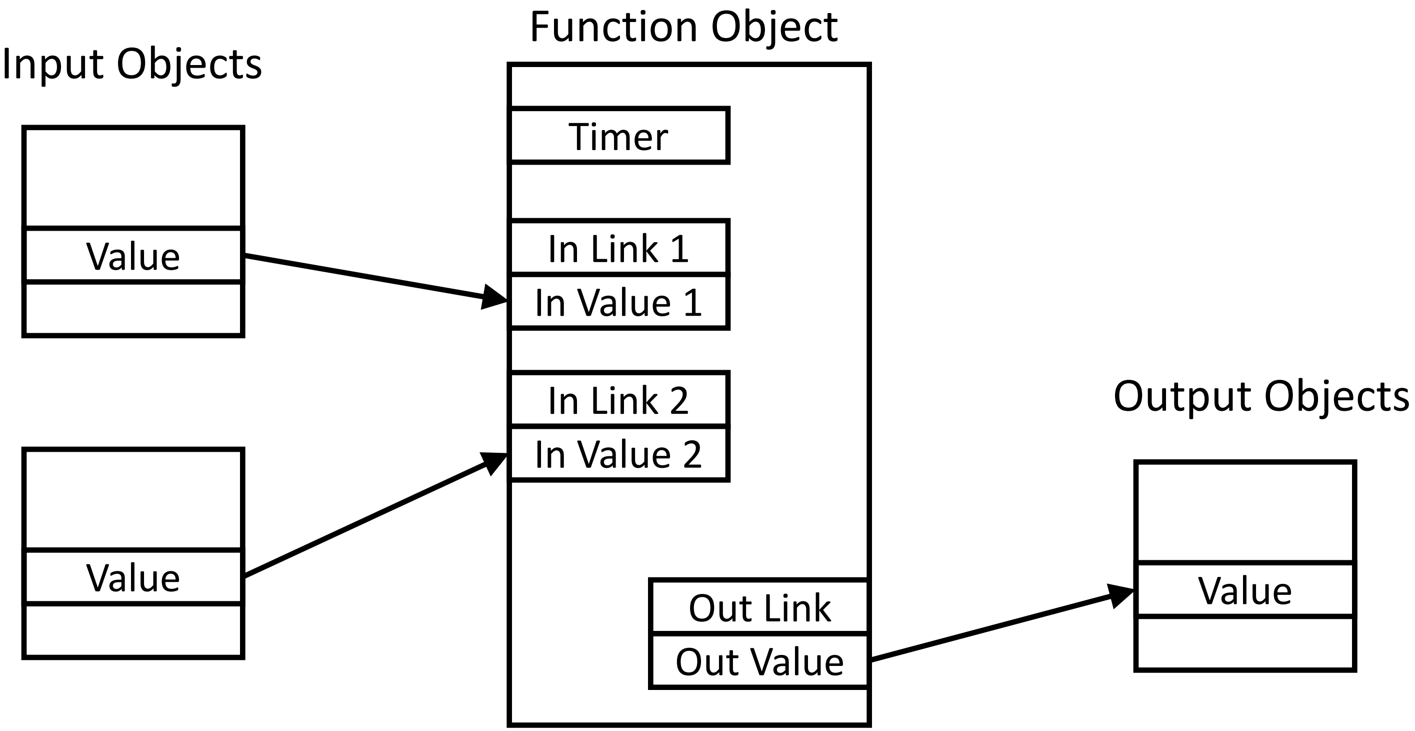
ObjectFlow – DFG wrapper

- 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)

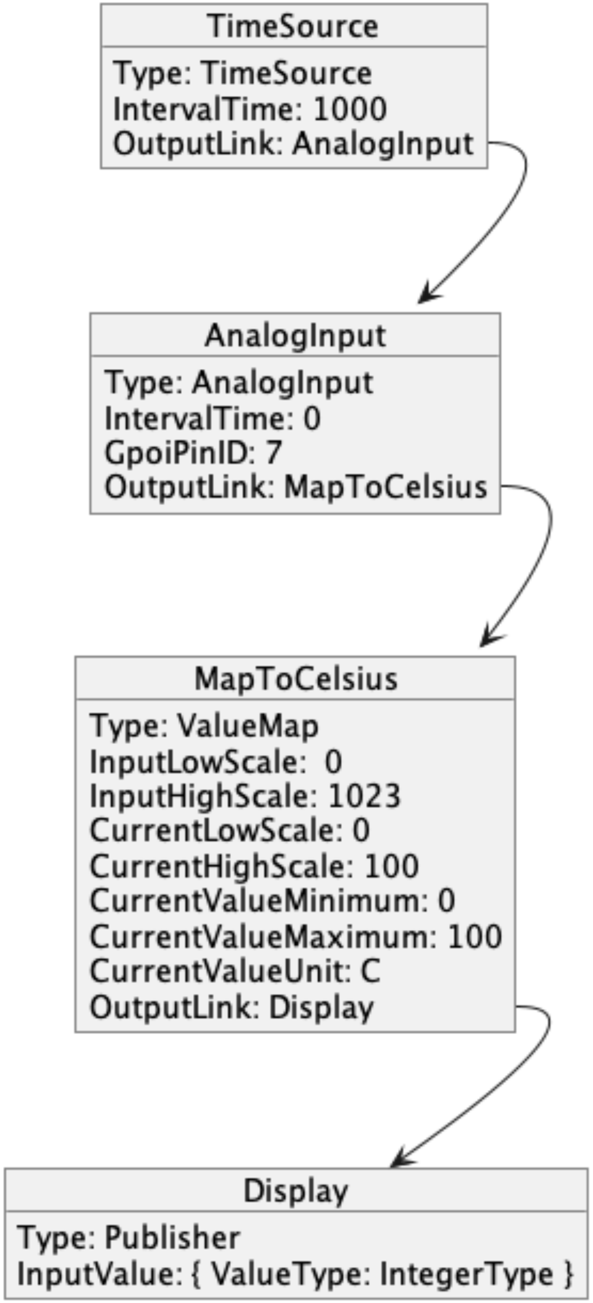
Example graph

```
TimeSource:
  Type: TimeSource
  IntervalTime: 1000
  TimerOutputLink: AnalogInput

AnalogInput:
  Type: AnalogInput
  GpioPinID: 7
  IntervalTime: 0
  OutputLink: MapToCelsius

MapToCelsius:
  Type: ValueMap
  InputLowScale:  0
  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: MapToCelsius

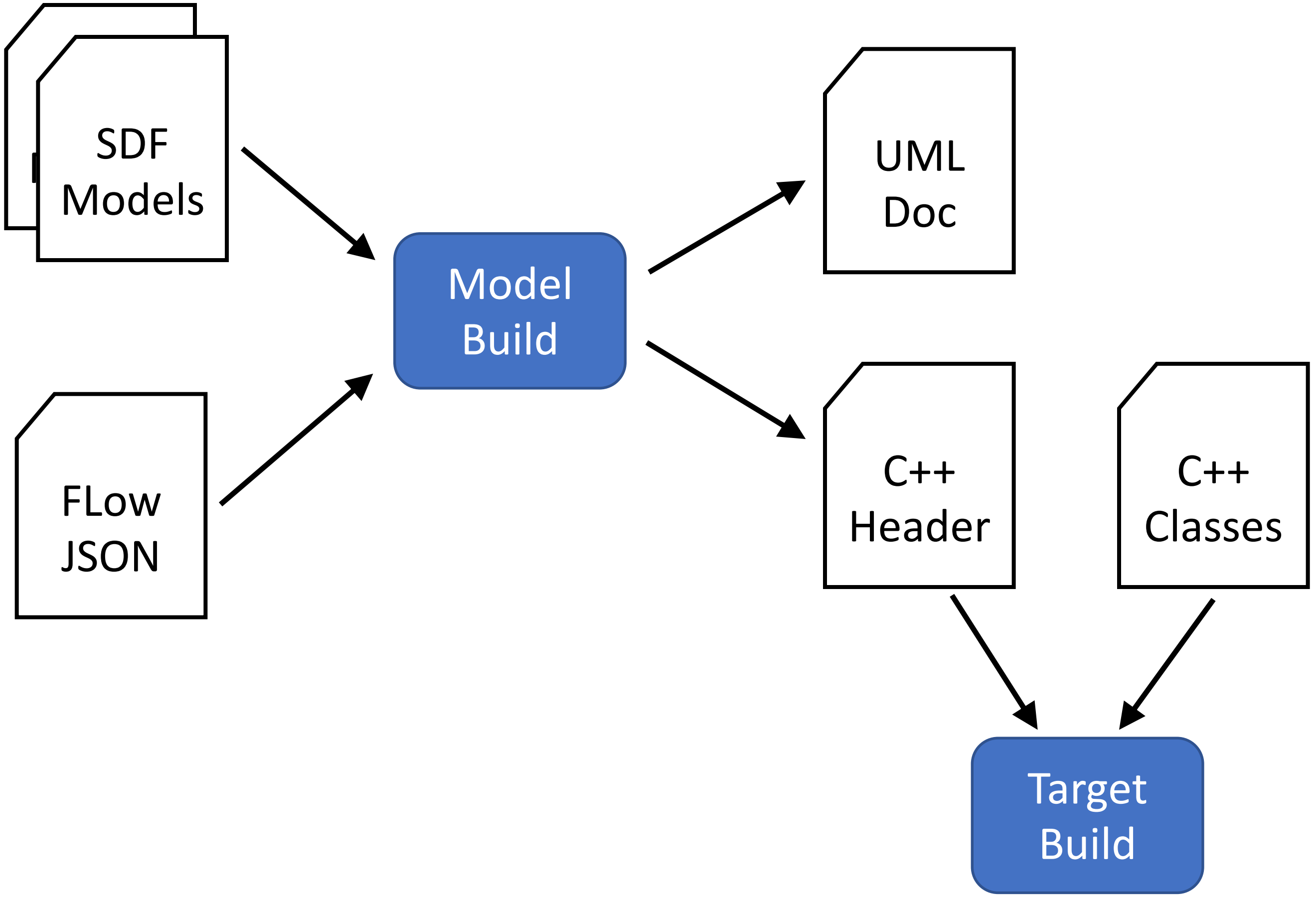
MapToCelsius
Type: ValueMap
InputLowScale: 0
InputHighScale: 1023
CurrentLowScale: 0
CurrentHighScale: 100
CurrentValueMinimum: 0
CurrentValueMaximum: 100
CurrentValueUnit: C
OutputLink: Display

Display
Type: Publisher
InputValue: { ValueType: IntegerType }

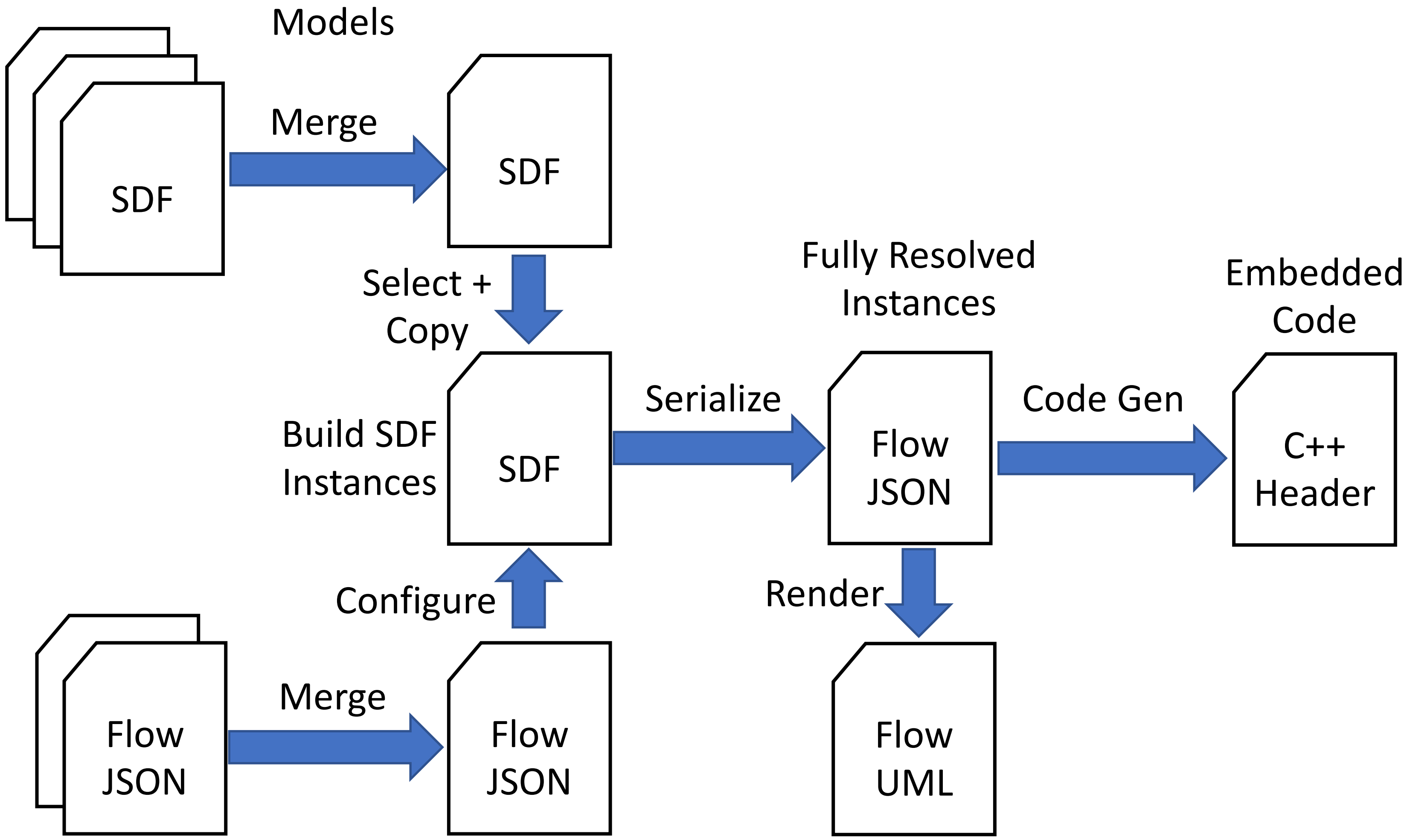
ObjectFlow - Tools

- 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.)

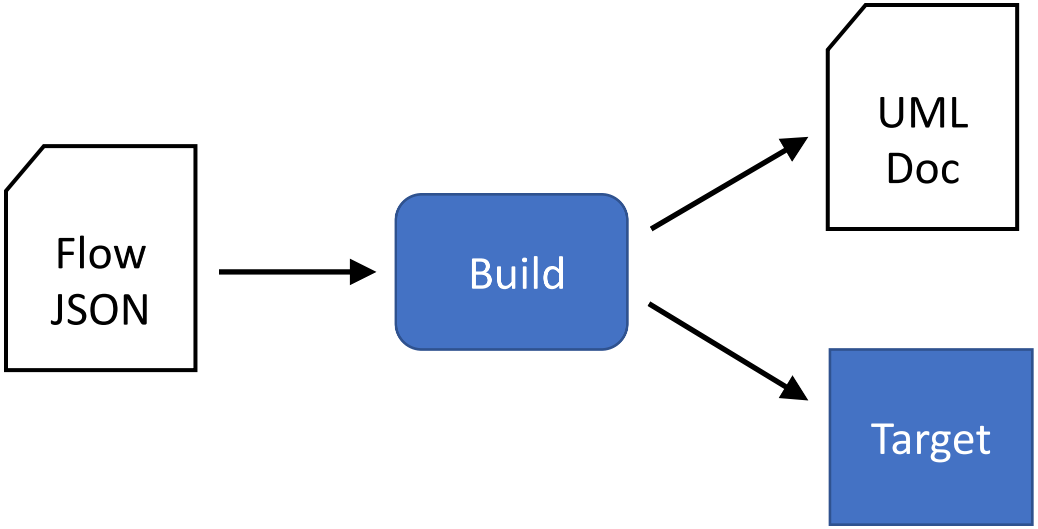
High Level Process



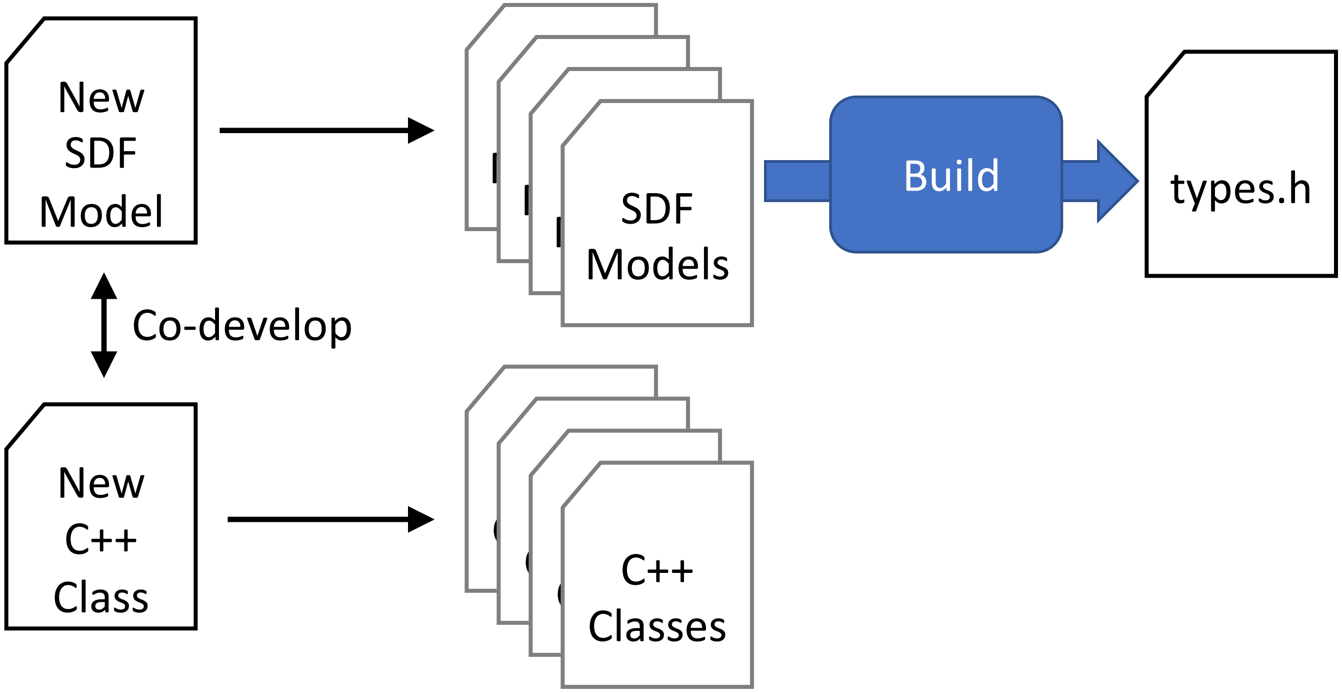
Build Process



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:
        sdfRef: /#/sdfData/TypeID/ObjectType/Publisher  => TypeID: { const: 43008 }

    # 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
```

Example SDF Instance

```
defaultnamespace: objectflow

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 }
```

Simplified DSL

```
defaultnamespace: objectflow

sdfThing:
  # Instance Graph
  InstanceGraph:
    sdfRef: /#/sdfThing/ObjectList
    # Objects in the graph
    sdfThing:

      TimeSource:
        sdfRef: /#/sdfThing/TimeSource
        sdfThing:
          IntervalTime:
            sdfProperty:
              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 }
```

```
TimeSource:
  Type: TimeSource
  IntervalTime: 1000
  TimerOutputLink: AnalogInput

AnalogInput:
  Type: AnalogInput
  GpioPinID: 7
  OutputLink: MapToCelsius
```

Reserved LWM2M Types

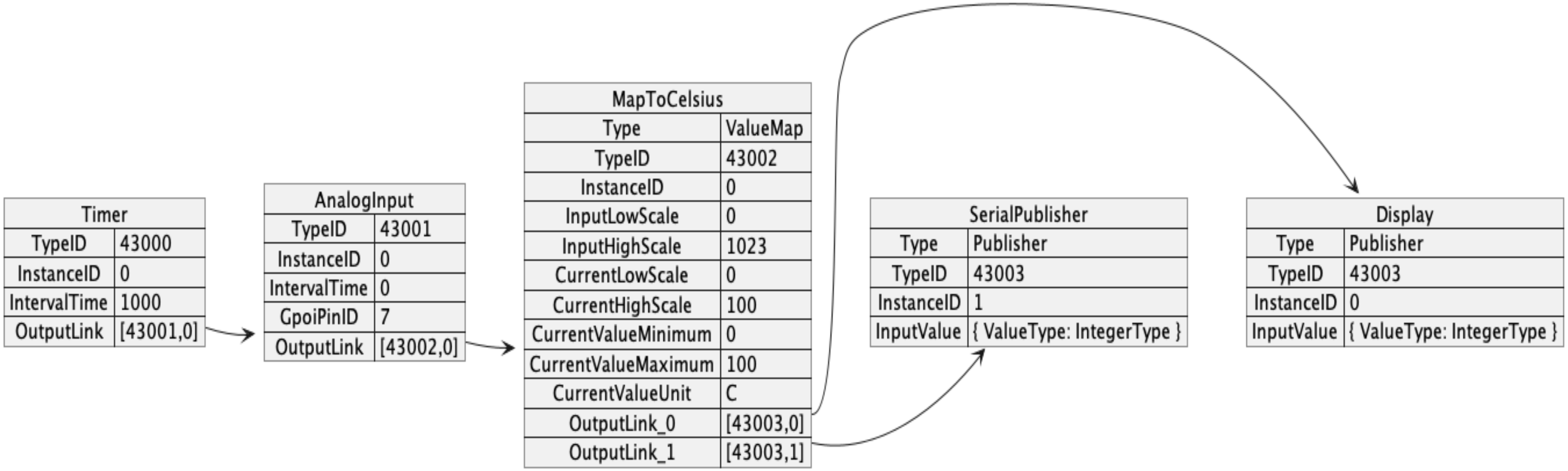
```
TypeID:
  ResourceType:
    InputLinkType: { const: 27000 }
    OutputLinkType: { const: 27001 }
    InputValueType: { const: 27002 }
    CurrentValueType: { const: 27003 }
    OutputValueType: { const: 27004 }
    CurrentTimeType: { const: 27005 }
    IntervalTimeType: { const: 27006 }
    LastActivationTimeType: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

SDF Defined

Generated C++ Header

```
#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



Timer	
TypeID	43000
InstanceID	0
IntervalTime	1000
OutputLink	[43001,0]

AnalogInput	
TypeID	43001
InstanceID	0
IntervalTime	0
GpoiPinID	7
OutputLink	[43002,0]

MapToCelsius	
Type	ValueMap
TypeID	43002
InstanceID	0
InputLowScale	0
InputHighScale	1023
CurrentLowScale	0
CurrentHighScale	100
CurrentValueMinimum	0
CurrentValueMaximum	100
CurrentValueUnit	C
OutputLink_0	[43003,0]
OutputLink_1	[43003,1]

SerialPublisher	
Type	Publisher
TypeID	43003
InstanceID	1
InputValue	{ ValueType: IntegerType }

Display	
Type	Publisher
TypeID	43003
InstanceID	0
InputValue	{ ValueType: IntegerType }