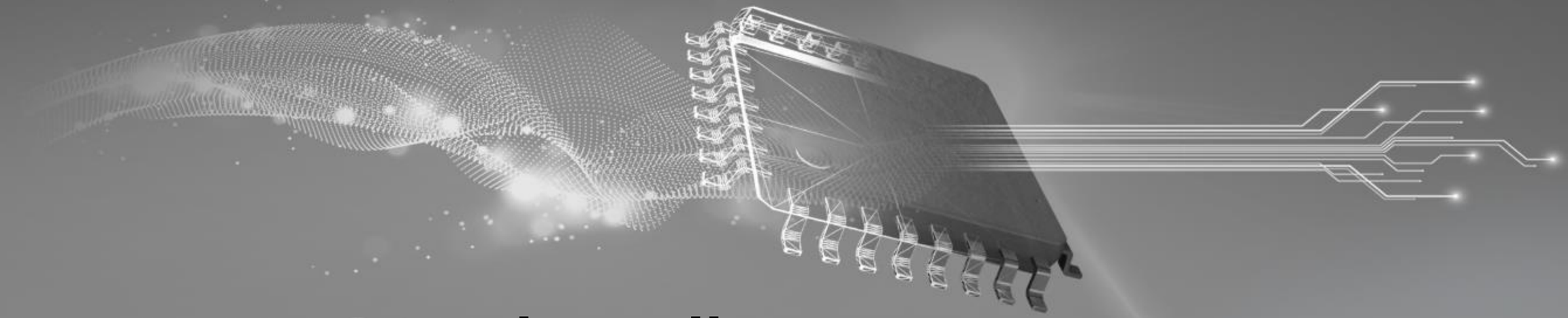
TI TECH DAYS



MMWAVE-SDK deep dive
Easy evaluation and development of mmWave systems with software development kit

Nitin Sakhuja - Industrial mmWave Radar Applications

MMWAVE-SDK deep dive

TI's MMWAVE-SDK (MilliMeter Wave Software Development Kit) is a unified software platform for the TI mmWave Sensing Portfolio, providing easy setup and fast out-of-the-box access to evaluation and development.

This training provides an overview of the MMWAVE-SDK 3.x architecture and the various building blocks such as Data Processing Units (DPUs) and Data Processing Chains(DPCs). It also provides a deeper look into the components with software execution flows accompanied with source code references from the MMWAVE-SDK Out of Box Demo point cloud processing chain.

We also present some example applications where the Out of box point cloud detection chain is extended to develop more complex mmWave applications such as Long Range People Detection and Tracking Demo, Traffic Monitoring Demo and Area Scanner Demo.

What you'll learn:

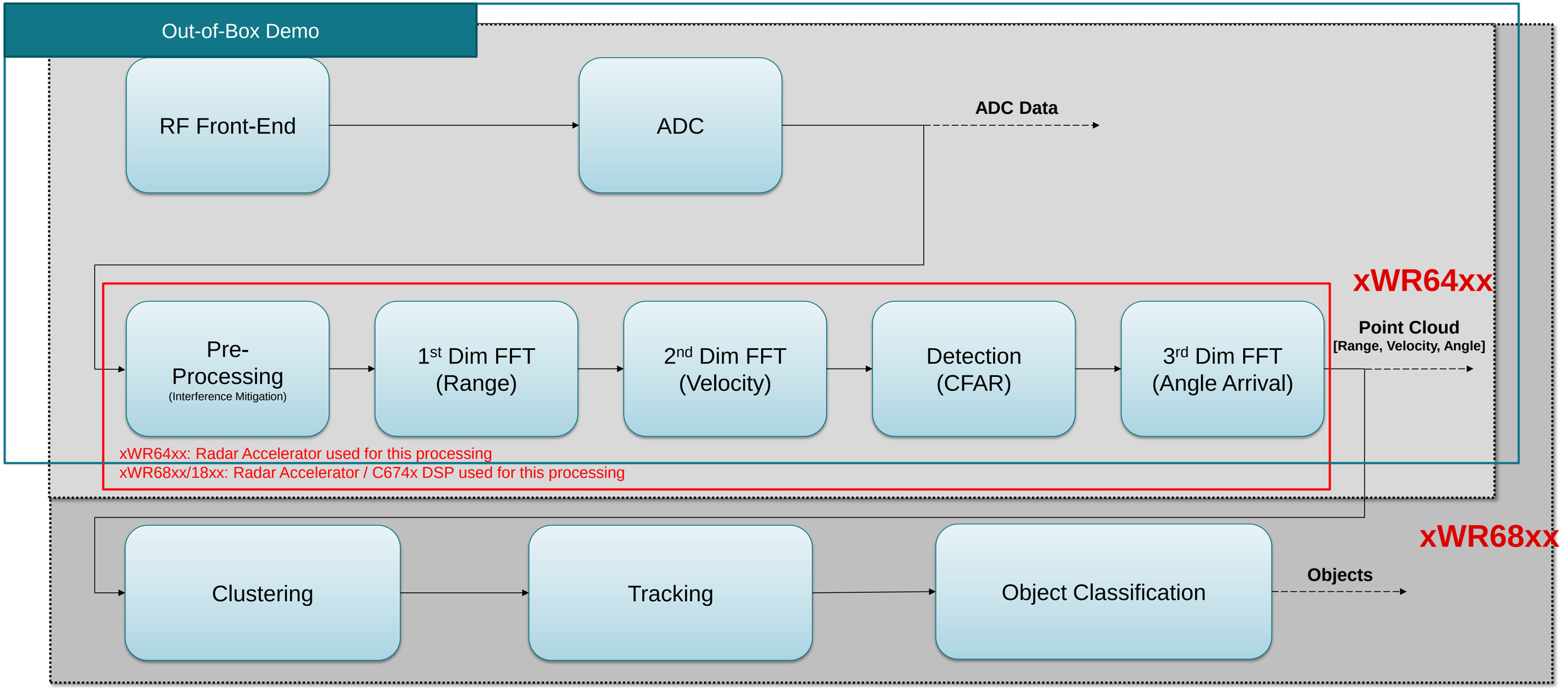
- TI MMWAVE-SDK architecture and it's various building blocks such as DPCs and DPUs
- Understand DPM, DPC and DPU execution flows e.g. initialization and runtime operation using source code references
- Developing custom components to extend the out of box processing chain and available examples.

Agenda

- MMWAVE-SDK
  - Architecture overview
  - Data path design
- Data path deep dive
  - Initialization
  - Configuration
  - Execution (Runtime view)
- DPUs and DPCs in MMWAVE-SDK 3.x
  - DPUs: Range, Static-Clutter removal, Doppler, CFAR-CA and AoA
  - DPCs: HWA and DSP based object detection chains
- Software development and debugging
  - Development resources
  - MMWAVE-SDK debugging
- Extending SDK architecture for advanced applications
  - Considerations for developing custom DPUs and DPCs
  - Custom DPUs and DPCs in Industrial Toolbox
  - Demo: Long Range People Tracking and, Traffic Monitoring
  - Demo: Area Scanner and, Automated Doors and Gates

MMWAVE-SDK - Architecture Overview

mmWave signal processing



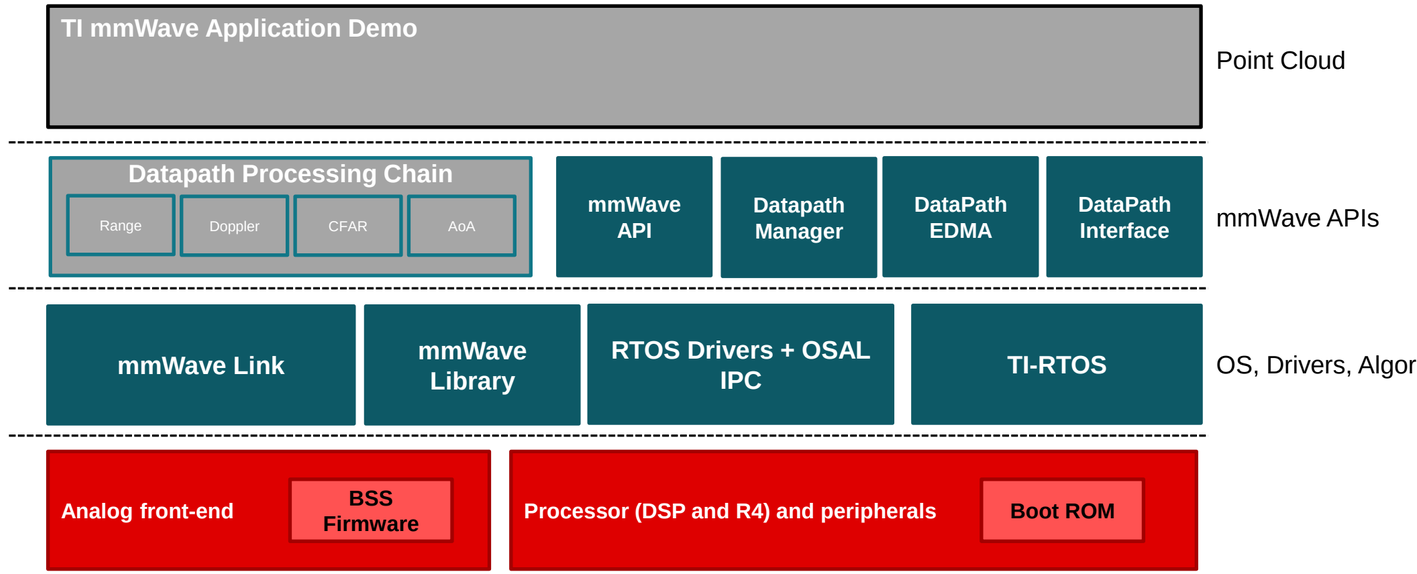
mmWave SDK contents

- Building blocks
  - RTOS, Drivers, and RadarSS firmware
  - Scalable data processing blocks and chains to work on HWA or DSP
  - Layered / API based Radar analog front end (AFE) programming
  - Pre-built software blocks and chains for basic FMCW Radar signal processing
  - Catalog of mmWave signal processing algorithms optimized for C674x DSPs including tracker
  - Package for high-security (HS) devices to enable programming encryption keys and encrypt/authenticate program binaries
- Demonstrations and examples
  - TI RTOS based
  - Out of box demo with easy configurability via TI Cloud-based or offline GUI
  - Representation of point cloud and benchmarking data from demo via GUI
- Documentation
  - Associated tools: Code Composer Studio, TI-RTOS, Uniflash
  - Available at http://www.ti.com/tool/MMWAVE-SDK

mmWave SDK architecture

Main highlights:

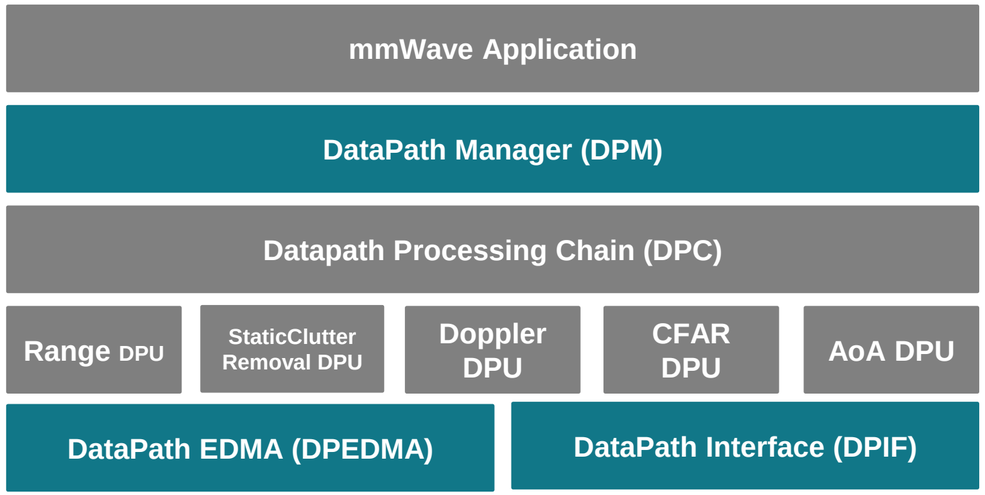
- Foundational components for SOC enablement – RTOS, Drivers, mmWaveLink, mmWaveLib
- RF Front-end completely abstracted using mmWaveLink
- mmWave API simplifies device integration of mmWaveLink
- Data path layer is an abstraction over existing driver APIs in the data flow
- Separation of data processing units and chain from the application
- Simpler application that does the instantiation of the Datapath layer



MMWAVE-SDK – Datapath Design

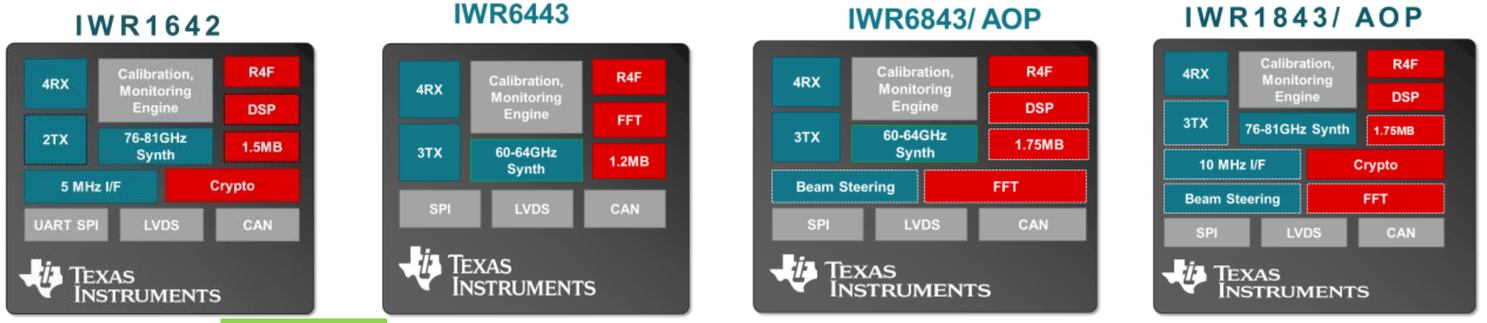
Datapath Layer Design

- **DPM: Datapath manager**
  - Foundation layer that enables the "scalability" aspect of the architecture.
- **DPIF: Standard Interface points in the Detection chain are defined**
  - Input ADC data, Radar Cube, Detection Matrix, Point cloud
- **DPUs: Data Translating function(s) from one interface point to the other are called “Data Processing Units”**
  - Range Processing (ADC data to Radar Cube)
  - Doppler Processing (Radar Cube to Detection Matrix)
  - CFAR and AoA (Detection Matrix to Point Cloud)
- **DPC: Data Processing Chain**
  - Chain of “data processing units” is called a data processing Chain. Ex: Detection DPC (ADC to Point Cloud).
  - This conforms to the DPM dictated API definition

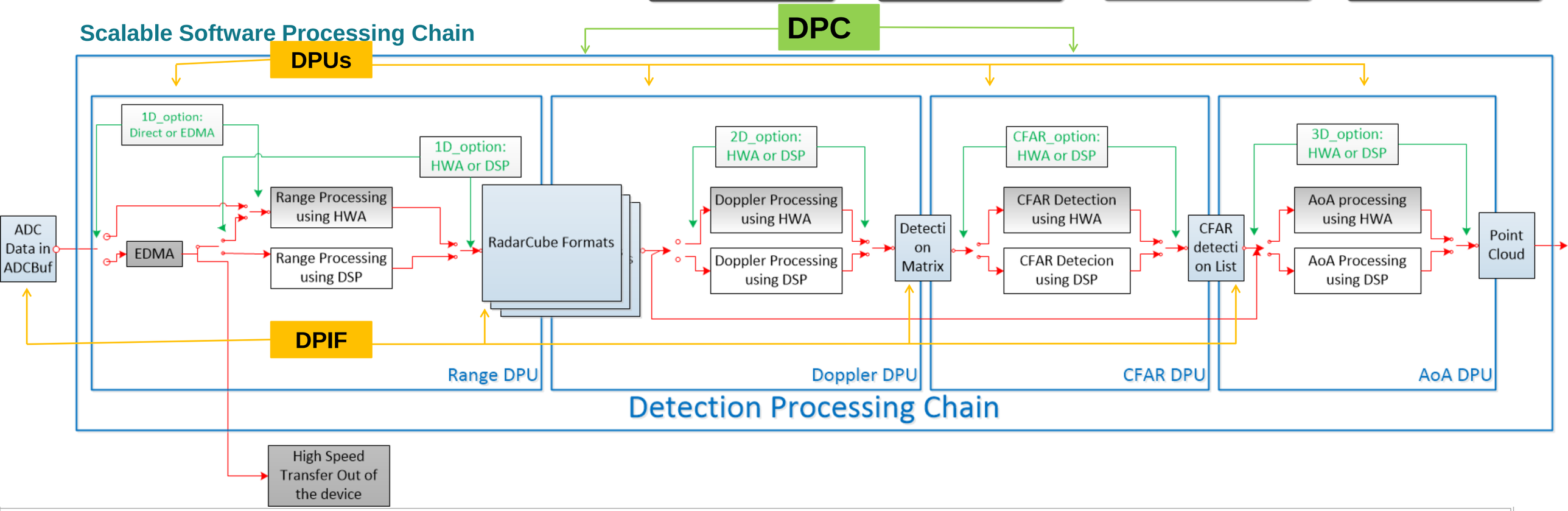


Scalable SW Chain

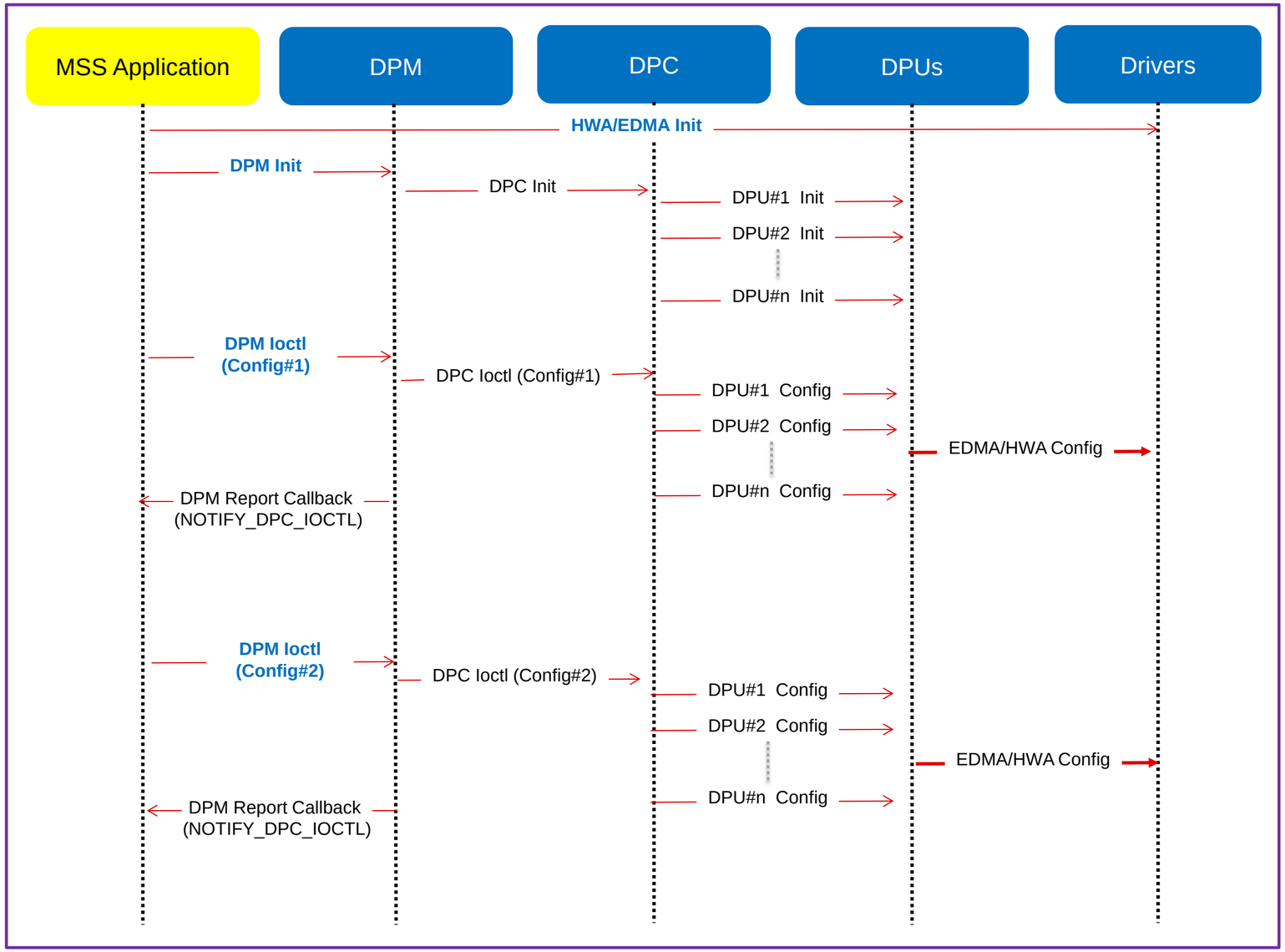
TI mmWave Sensor Portfolio



Scalable Software Processing Chain

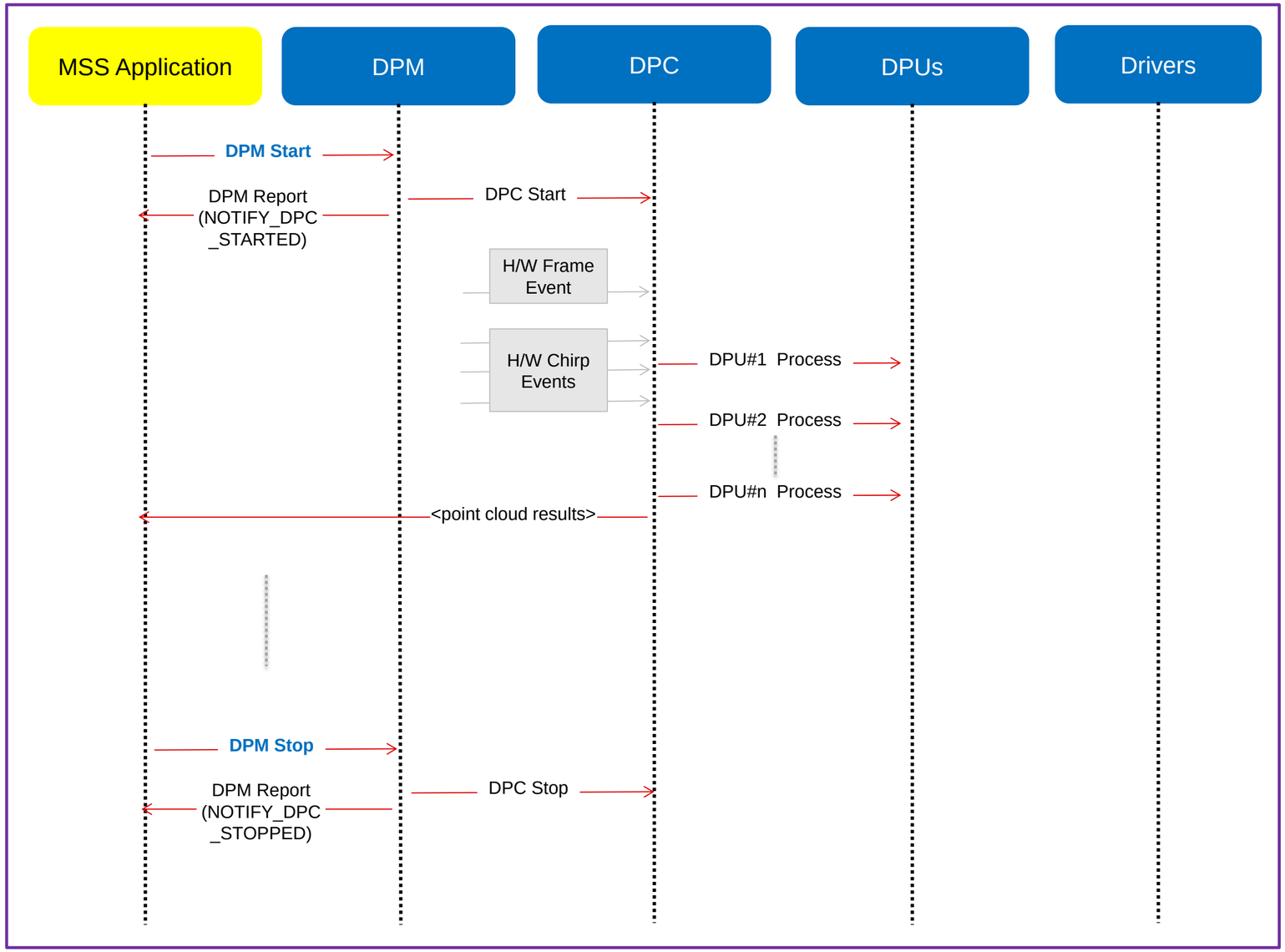


Typical call flow (1/2)



Config#1 and Config#2 are shown as examples here on how a config can be split into multiple shorrter structures as needed by a DPC. It is not mandatory to split into two. On the contrary, config can be split into even more smaller structures.

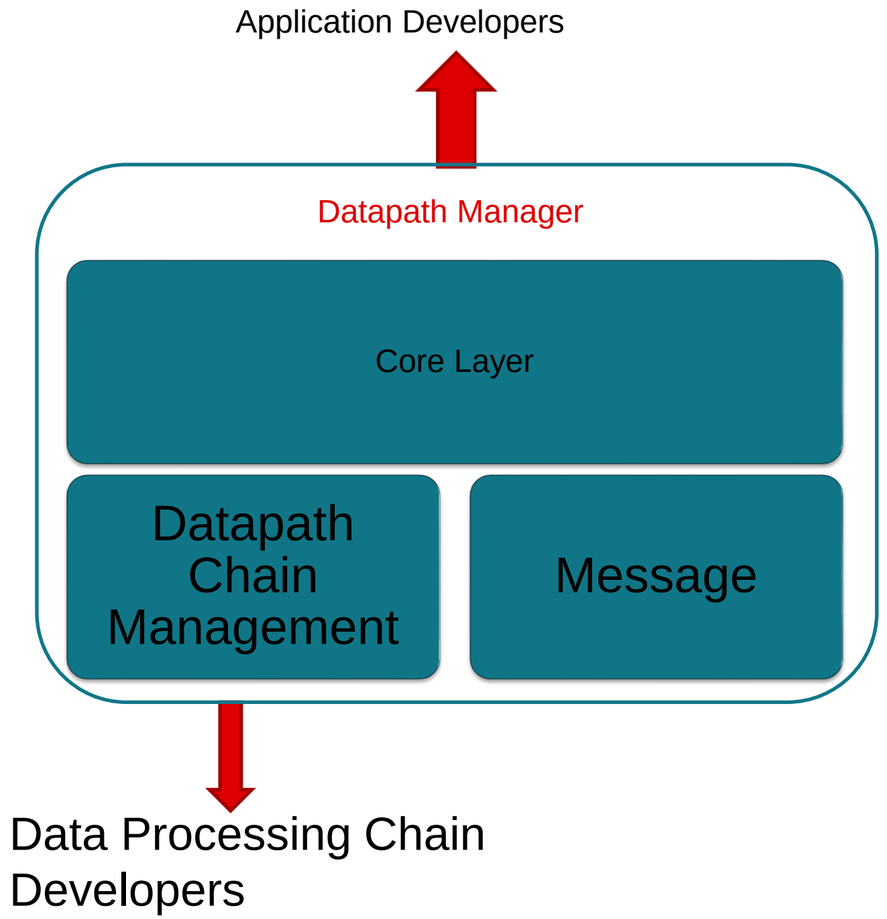
Typical call flow (2/2)



Data path deep dive

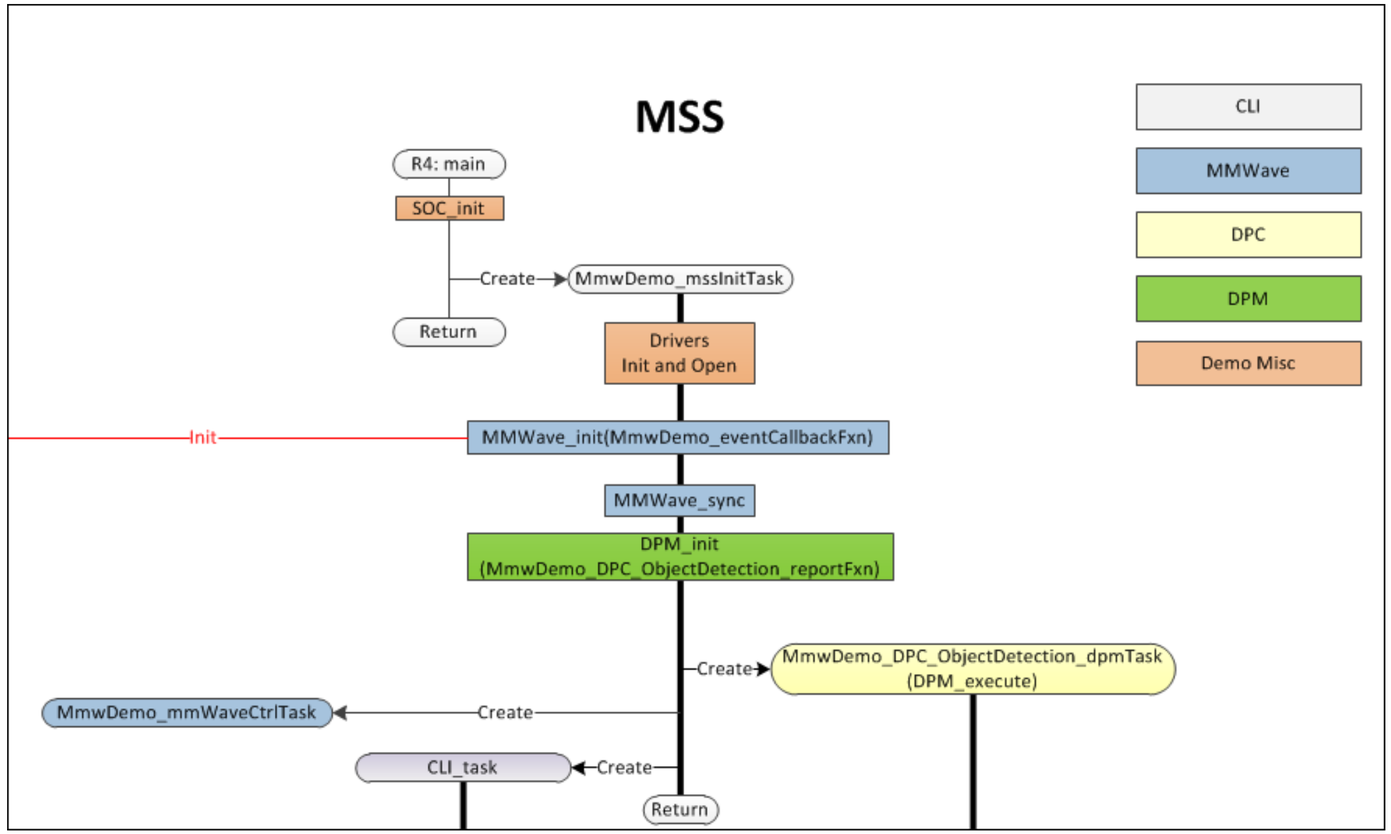
DPM: Datapath Manager

- Modular SW Architecture which provides an abstraction between the “Datapath Processing Chain” and the customer application.
  - Main task context which encapsulates the execution of DPC and DPUs
  - Application code instantiates DPM at start-up and registers a DPC.
- Provides a well-defined API
  - Exposed to the application to interface with the DPM
  - Exposed to the “*Data processing chain” developers* to be able to write their own code.
- Messaging mechanism
  - Send/Receive Configuration
  - Extends to Multiple-Thread/Core
  - Synchronized execution (No critical section required)
  - Response Mechanism with error code passing
- *Reporting mechanism* which allows applications to be notified about the status of the DPM/Datapath Processing Chain.



DPM Initialization

- Application code creates and initializes a DPM instance using the DPM_init function
- Application also creates a DPM task



Source: MMWAVE-SDK HTML documentation
C:\ti\mmwave_sdk_03_xx_xx_xx\docs\mmwave_sdk_module_documentation.html

DPM Initialization

- Application code creates and initializes a DPM instance using the DPM_init function
- Application also creates a DPM task

main.c (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\demo\xwr64xx\mmw) - GVIM

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2

```
3230     /* Launch the DPM Task */
3231     Task_Params_init(&taskParams);
3232     taskParams.priority  = MMWDEMO_DPC_OBJDET_DPM_TASK_PRIORITY;
3233     taskParams.stackSize = 4*1024;
3234     gMmwMCB.taskHandles.objDetDpmTask = Task_create(MmwDemo_DPC_ObjectDetection_dpmTask, &taskParams,
3235
3236     /**************************************************************************
```

main.c (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\demo\xwr64xx\mmw) - GVIM

File Edit Tools Syntax Buffers Window Help

3

```
2732  *  @b Description
2733  *  @n
2734  *      DPM Execution Task. DPM execute results are processed here:
2735  *      a) Transmits results through UART port.
2736  *      b) Updates book-keeping code for timing info.
2737  *      c) Notifies DPC that results have been exported (using DPC IOCTL command)
2738  *
2739  *  @retval
2740  *      Not Applicable.
2741  */
2742 static void MmwDemo_DPC_ObjectDetection_dpmTask(UArg arg0, UArg arg1)
2743 {
2744     int32_t     retVal;
2745     DPM_Buffer  resultBuffer;
2746     DPC_ObjectDetection_ExecuteResultExportedInfo exportInfo;
2747     DPC_ObjectDetection_ExecuteResult *result;
2748
2749     while (1)
2750     {
2751         /* Execute the DPM module: */
2752         retVal = DPM_execute (gMmwMCB.dataPathObj.objDetDpmHandle, &resultBuffer);
2753         if (retVal < 0) {
```

main.c (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\demo\xwr64xx\mmw) - GVIM

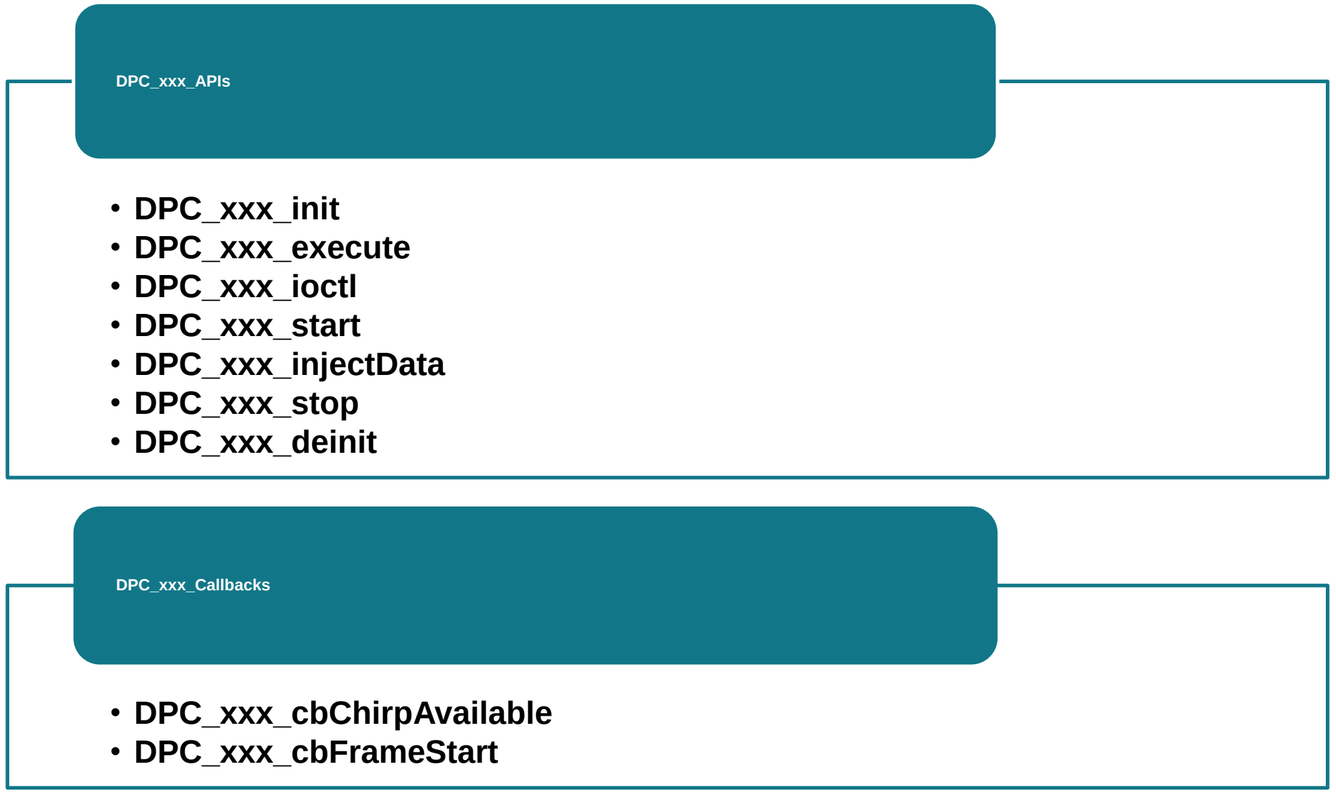
File Edit Tools Syntax Buffers Window Help

1

```
3185     /**************************************************************************
3186      * Initialization of the DPM Module:
3187      **************************************************************************/
3188     memset ((void *)&objDetInitParams, 0, sizeof(DPC_ObjectDetection_InitParams));
3189
3190     /* Note this must be after MmwDemo_dataPathOpen() above which opens the hwa
3191      * and edma drivers */
3192     objDetInitParams.hwaHandle = gMmwMCB.dataPathObj.hwaHandle;
3193     for (edmaCCIdx = 0; edmaCCIdx < EDMA_NUM_CC; edmaCCIdx++)
3194     {
3195         objDetInitParams.edmaHandle[edmaCCIdx] = gMmwMCB.dataPathObj.edmaHandle[edmaCCIdx];
3196     }
3197
3198     /* Memory related config */
3199     objDetInitParams.L3ramCfg.addr = (void *)&gMmwL3[0];
3200     objDetInitParams.L3ramCfg.size = sizeof(gMmwL3);
3201     objDetInitParams.CoreLocalRamCfg.addr = &gDPC_ObjDetTCM[0];
3202     objDetInitParams.CoreLocalRamCfg.size = sizeof(gDPC_ObjDetTCM);
3203
3204     /* Call-back config */
3205     objDetInitParams.processCallBackCfg.processFrameBeginCallBackFxn =
3206         MmwDemo_DPC_ObjectDetection_processFrameBeginCallBackFxn;
3207     objDetInitParams.processCallBackCfg.processInterFrameBeginCallBackFxn =
3208         MmwDemo_DPC_ObjectDetection_processInterFrameBeginCallBackFxn;
3209
3210     memset ((void *)&dpmInitCfg, 0, sizeof(DPM_InitCfg));
3211
3212     /* Setup the configuration: */
3213     dpmInitCfg.socHandle        = gMmwMCB.socHandle;
3214     dpmInitCfg.ptrProcChainCfg  = &gDPC_ObjectDetectionCfg;
3215     dpmInitCfg.instanceId       = 0xFEEDFEED;
3216     dpmInitCfg.domain           = DPM_Domain_LOCALIZED;
3217     dpmInitCfg.reportFxn        = MmwDemo_DPC_ObjectDetection_reportFxn;
3218     dpmInitCfg.arg              = &objDetInitParams;
3219     dpmInitCfg.argSize          = sizeof(DPC_ObjectDetection_InitParams);
3220
3221     /* Initialize the DPM Module: */
3222     gMmwMCB.dataPathObj.objDetDpmHandle = DPM_init (&dpmInitCfg, &errCode);
3223     if (gMmwMCB.dataPathObj.objDetDpmHandle == NULL)
3224     {
3225         System_printf ("Error: Unable to initialize the DPM Module [Error: %d]\n", errCode);
3226         MmwDemo_debugAssert (0);
3227         return;
```

Pointer to DPC

DPC: Data Processing Chain

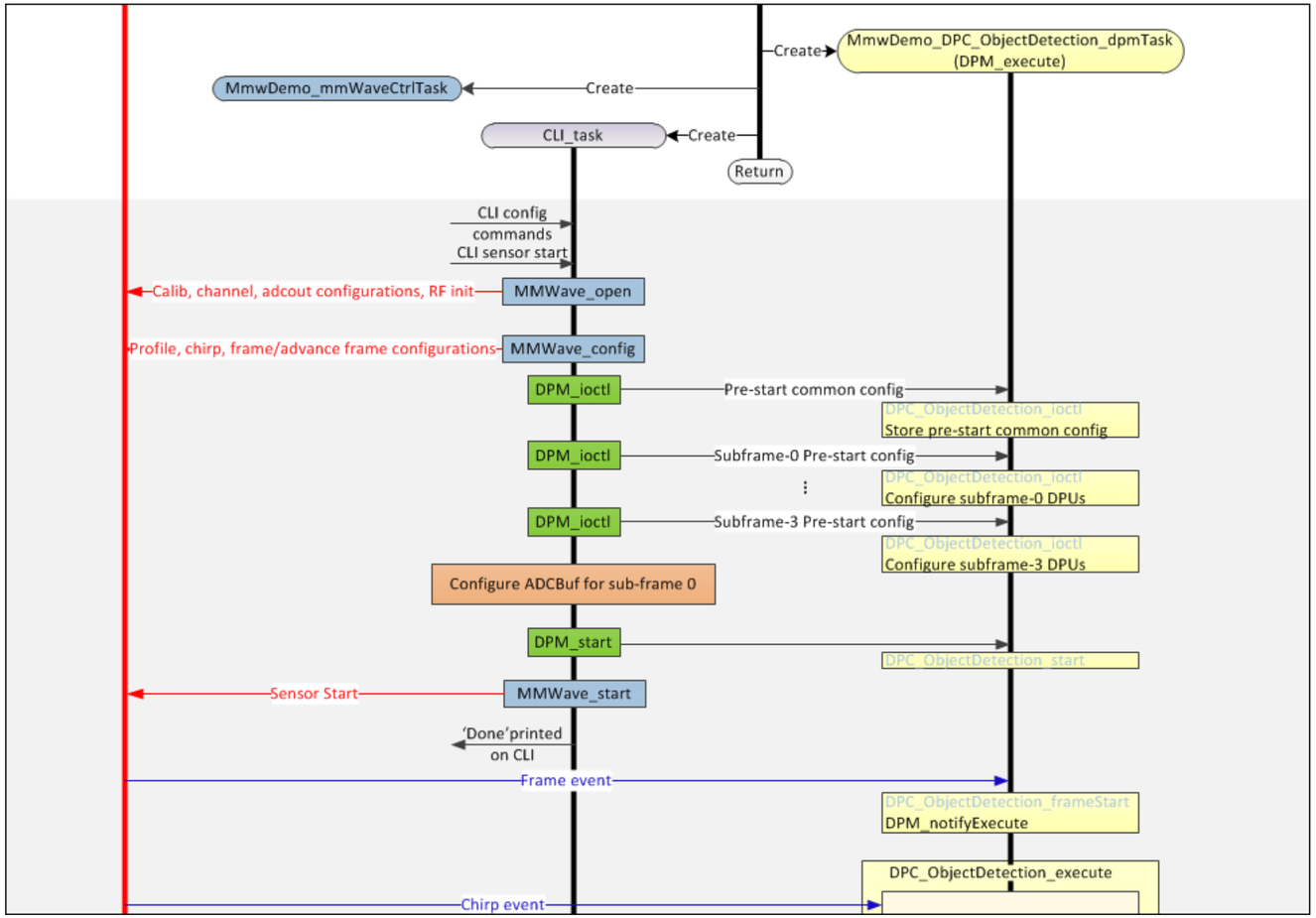


- All external DPC APIs starts with DPC_. DPC unique name follows next (follows coding guidelines).
  - DPC_ObjectDetection_Init
- External Mandatory APIs follows the prototype defined by the “Datapath Manager”
- DPCs have flexibility in defining their own content within the individual structure
- DPC that is split between MSS and DSS will expose two set of APIs - one for MSS and one for DSS. Depending on the functionality split between the two domains, not all APIs need to be implemented on the two domains

For more details, refer to docs folder in each of the DPCs

DPC Initialization

- Application registers the DPC with DPM during DPM creation.
- Application calls DPM init which calls the DPC's registered init function
- Application calls DPM_ioctl with different message types
- DPM_ioctl invokes the DPC's registered ioctl function with:
  - Pre-start common config message (common to all sub-frames) and
  - Sub-frame specific Pre-start config messages.
- DPC handles the messages in the ioctl function and performs the corresponding configuration.



Source: MMWAVE-SDK HTML documentation
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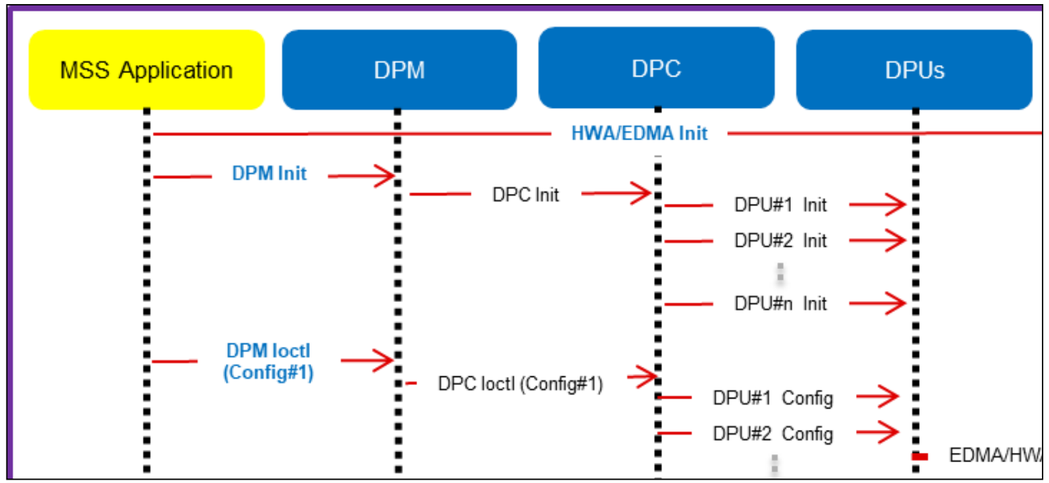
DPC Initialization

- Application registers the DPC with DPM during DPM creation.
- Application calls DPM init which calls the DPC's registered init function
- Application calls DPM_ioctl with different message types
- DPM_ioctl internally invokes the DPC's registered ioctl function and passes the message to it
- DPC handles the message in the ioctl function and performs the corresponding configuration
- Refer to the call flow below



objectdetection.c (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\datapath\dpc\objectdetection\objdethwa\src) - GVIM

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1

```
357  * @brief   Global used to register Object Detection DPC in DPM
358  */
359 DPM_ProcChainCfg gDPC_ObjectDetectionCfg =
360 {
361     DPC_ObjectDetection_init,           /* Initialization Function:
362     DPC_ObjectDetection_start,          /* Start Function:
363     DPC_ObjectDetection_execute,        /* Execute Function:
364     DPC_ObjectDetection_ioctl,          /* Configuration Function:
365     DPC_ObjectDetection_stop,           /* Stop Function:
366     DPC_ObjectDetection_deinit,         /* Deinitialization Function:
367     NULL,                               /* Inject Data Function:
368     NULL,                               /* Chirp Available Function:
369     DPC_ObjectDetection_frameStart      /* Frame Start Function:
370 };
371
372 /* @} */
```

main.c (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\demo\xwr64xx\mmw) - GVIM

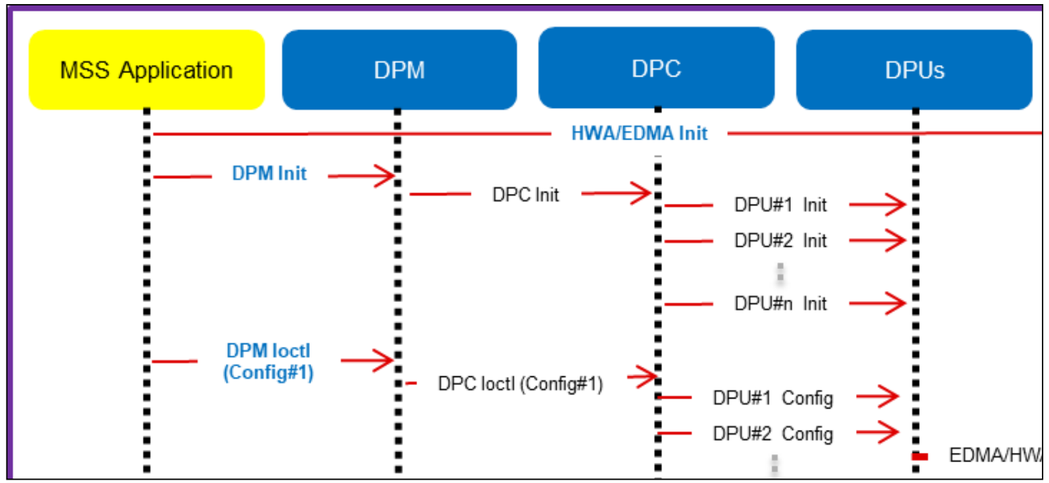
File Edit Tools Syntax Buffers Window Help

2

```
3207     objDetInitParams.processCallBackCfg.processInterFrameBeginCallB
3208         MmwDemo_DPC_ObjectDetection_processInterFrameBeginCallBackF
3209
3210     memset ((void *)&dpmInitCfg, 0, sizeof(DPM_InitCfg));
3211
3212     /* Setup the configuration: */
3213     dpmInitCfg.socHandle        = gMmwMCB.socHandle;
3214     dpmInitCfg.ptrProcChainCfg  = &gDPC_ObjectDetectionCfg;
3215     dpmInitCfg.instanceId       = 0xFEEDFEED;
3216     dpmInitCfg.domain           = DPM_Domain_LOCALIZED;
3217     dpmInitCfg.reportFxn        = MmwDemo_DPC_ObjectDetection_reportFxn;
3218     dpmInitCfg.arg              = &objDetInitParams;
3219     dpmInitCfg.argSize          = sizeof(DPC_ObjectDetection_InitParams);
3220
3221     /* Initialize the DPM Module: */
3222     gMmwMCB.dataPathObj.objDetDpmHandle = DPM_init (&dpmInitCfg, &errCode);
```

DPC Configuration

- Application registers the DPC with DPM during DPM creation.
- Application calls DPM init which calls the DPC's registered init function
- Application calls DPM_ioctl with different message types (i.e. commands)
- DPM_ioctl internally invokes the DPC's registered ioctl function and passes the message to it
- DPC handles the message in the ioctl function and performs the corresponding configuration
- Refer to the call flow below



mmw_cli.c (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\demo\xwr64xx\mmw) - GVIM1

File Edit Tools Syntax Buffers Window Help

```
125 static int32_t MmwDemo_CLISensorStart (int32_t argc, char* argv[])
126 {
127     bool doReconfig = true;
128     int32_t     retVal = 0;
```

1

```
304         /* if MmwDemo_openSensor has non-first time related processing, call here ag
305         /* call sensor config */
306         CLI_getMMWaveExtensionConfig (&gMmwMCB.cfg.ctrlCfg);
307         retVal = MmwDemo_configSensor();
308         if(retVal != 0)
```

2

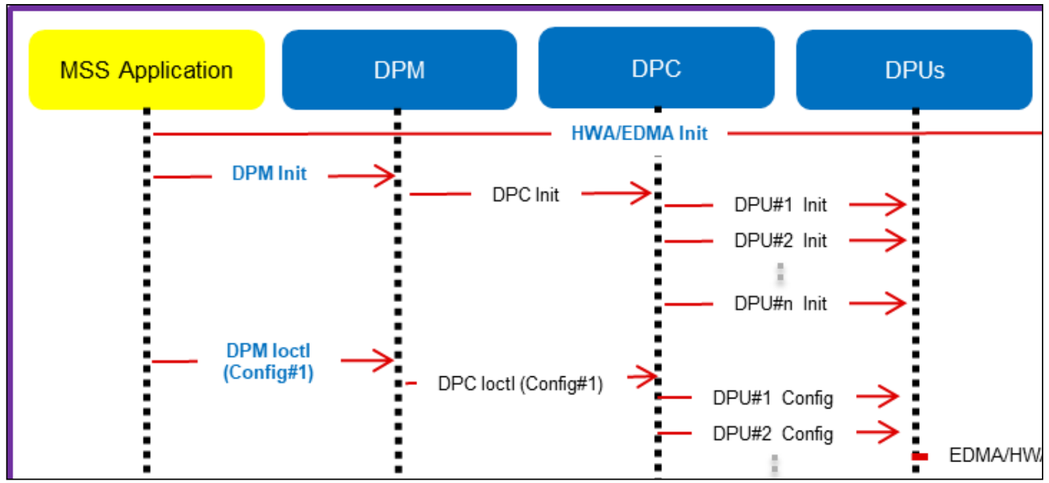
main.c (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\demo\xwr64xx\mmw) - GVIM

File Edit Tools Syntax Buffers Window Help

```
1206         System_printf ("Error: mmWave Config failed [Error code: %d Subsystem: %d]\n
1207 3                       mmWaveErrorCode, subsysErrorCode);
1208         goto exit;
1209     }
1210     else
1211     {
1212         errCode = MmwDemo_dataPathConfig();
1213         goto exit;
1214     }
1215
1572     /* DPC pre-start common config */
1573     errCode = DPM_ioctl (dataPathObj->objDetDpmHandle,
1574                          DPC_OBJDET_IOCTL__STATIC_PRE_START_COMMON_CFG,
1575 4                       &dataPathObj->objDetCommonCfg.preStartCommonCfg,
1576                          sizeof (DPC_ObjectDetection_PreStartCommonCfg));
1577
1578     if (errCode < 0)
1579     {
1580         System_printf ("Error: Unable to send DPC_OBJDET_IOCTL__STATIC_PRE_START_COM
1581         goto exit;
1582     }
```

DPC Configuration (continued)

- Application registers the DPC with DPM during DPM creation.
- Application calls DPM init which calls the DPC's registered init function
- Application calls DPM_ioctl with different message types
- DPM_ioctl internally invokes the DPC's registered ioctl function and passes the message to it
- DPC handles the message in the ioctl function and performs the corresponding configuration
- Refer to the call flow below



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objectdetection.c (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\datapath\dpc\objectdetection\objdethwa\src) - GVIM

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```
2350  */
2351 static int32_t DPC_ObjectDetection_ioctl
2352 (
2353     DPM_DPCHandle   handle,
2354     uint32_t            cmd,
2355     void*               arg,
2356     uint32_t            argLen
2357 )
2358 {
2359     ObjDetObj   *objDetObj;
2360     SubFrameObj *subFrmObj;
2361     int32_t      retVal = 0;
2362
2363     /* Get the DSS MCB: */
2364     objDetObj = (ObjDetObj *) handle;
2365     DebugP_assert(objDetObj != NULL);
2366
2367     /* Process the commands. Process non sub-frame specific ones first
2368      * so the sub-frame specific ones can share some code. */
2369     if (cmd == DPC_OBJDET_IOCTL__TRIGGER_FRAME)
2370     {
2371         DPC_ObjectDetection_frameStart(handle);
2372     }
2373     else if (cmd == DPC_OBJDET_IOCTL__STATIC_PRE_START_COMMON_CFG)
2374     {
2375         DPC_ObjectDetection_PreStartCommonCfg *cfg;
2376         int32_t indx;
```

6

objectdetection.c (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\datapath\dpc\objectdetection\objdethwa\src) - GVIM

File Edit Tools Syntax Buffers Window Help

```
2415         }
2416     }
2417     else if (cmd == DPC_OBJDET_IOCTL__DYNAMIC_COMP_RANGE_BIAS_AND_RX_CHAN_PH
2418     {
2419         DPU_AoAProc_compRxChannelBiasCfg *inpCfg;
2420         DPU_AoAProc_compRxChannelBiasCfg outCfg;
2421         int32_t i;
2422
2423         DebugP_assert(argLen == sizeof(DPU_AoAProc_compRxChannelBiasCfg));
2424
2425         inpCfg = (DPU_AoAProc_compRxChannelBiasCfg*)arg;
2426
2427         for(i = 0; i < objDetObj->commonCfg.numSubFrames; i++)
```

DPU: Data Processing Units

DPU_xxx_init

- **DPU_xxx_InitParams_t**
- **errCode**
- **Handle**

DPU_xxx_config

- **DPU_Handle**
- **DPU_xxx_Config_t**
  - H/W Resources (EDMA, HWA, I/O buffer pointers, Scratch buffer pointers)
  - Frame/Sub-frame DPU Static Config (Ex: Num ADC Samples, Chirps/Frame, ADCBuf Config, Data Interface Desc)
  - Frame/Sub-frame DPU Dynamic Config (Ex: DC Range Calibration)
- **errCode**

DPU_xxx_process

- **DPU_Handle**
- **DPU_xxx_OutParams_t**
  - DPU_xxx_Stats_t
  - DPU optional specific Params (Ex: isLastChirp)
- **errCode**

DPU_xxx_control

- **DPU_Handle**
- **cmd**
- **args**
- **argSize**
- **errCode**

DPU_xxx_deinit

- **DPU_handle**
- **errCode**

- All external DPU APIs start with the prefix DPU_. DPU unique name follows next..Ex: DPU_RangeProcHWA_init
- Standard external APIs:
  - **Init**: one time initialization of DPU
  - **Config**: complete configuration of the DPU: hardware resources, static and dynamic (if supported by DPU)
    - **static config**: config that is static during ongoing frames
    - **dynamic config**: config that can be changed from frame to frame but only when process is not ongoing - ideally interframe time after DPC has exported the results for the frame
  - **Process**: the actual processing function of the DPU
  - **Control**: ioctl interface that allows higher layer to switch dynamic configuration during interframe time
  - **De-init**: de-initialization of DPU
- All memory allocations for I/O buffers and scratch buffers are outside the DPU since mmWave applications rely on memory overlay technique for optimization and that is best handled at application level
- All H/W resources must be allocated by application and passed to the DPU. This helps in keeping DPU platform agnostic as well as allows application to share the resources across DPU when DPU processing doesn't overlap in time.
- DPUs are OS agnostic and use OSAL APIs for needed OS services.

For more details, refer to docs folder in each of the DPUs

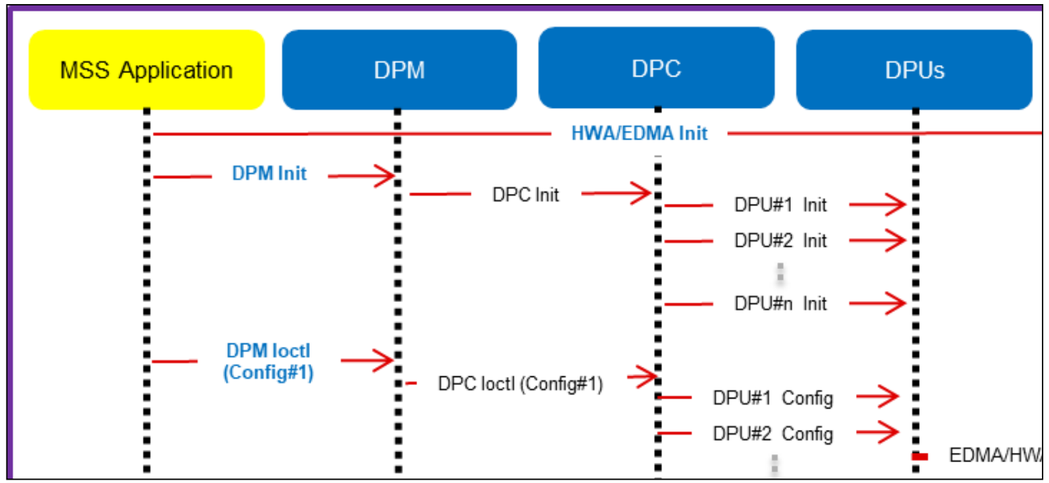
DPU Initialization

Recall from DPC Configuration…

- Application calls DPM init which calls the DPC's registered init function

- DPC_init calls the various DPU init functions in sequence, to create separate DPU instances for the number of sub-frames configured.

- Refer to the call flow below



objectdetection.c (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\datapath\dpc\objectdetection\objdethwa\src) - GVIM

File Edit Tools Syntax Buffers Window Help

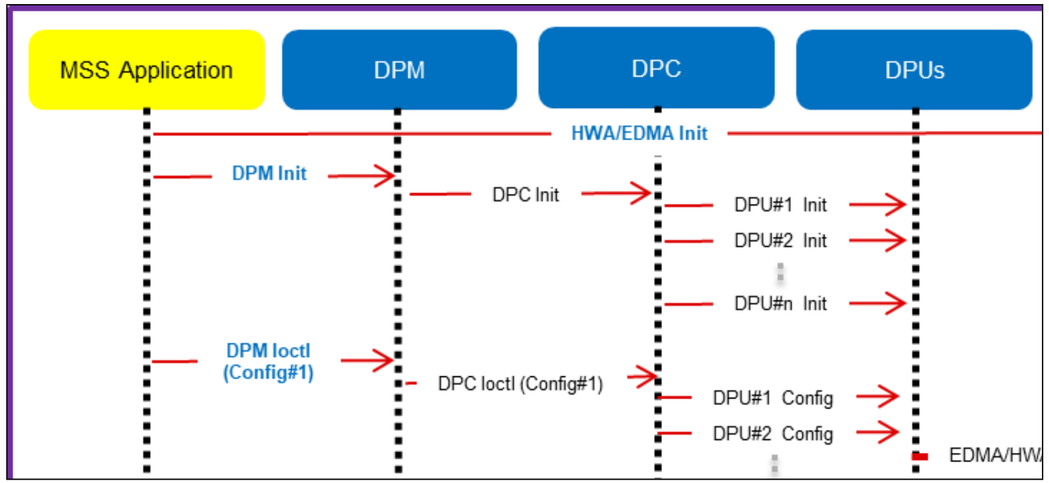
```
2825  *       Error   -   <0
2826  */
2827 static DPM_DPCHandle DPC_ObjectDetection_init
2828 (
2829     DPM_Handle          dpmHandle,
2830     DPM_InitCfg*        ptrInitCfg,
2831     int32_t*            errCode
2832 )
2833 {
2834     int32_t i;
2835     ObjDetObj     *objDetObj = NULL;
2836     SubFrameObj   *subFrmObj;
2837     DPC_ObjectDetection_InitParams *dpcInitParams;
2838     DPU_RangeProcHWA_InitParams rangeInitParams;
2839     DPU_AoAProcHWA_InitParams aoaInitParams;
2840     DPU_CFARCAProcHWA_InitParams cfarInitParams;
2841     DPU_DopplerProcHWA_InitParams dopplerInitParams;
2842     HWA_MemInfo         hwaMemInfo;
2907     rangeInitParams.hwaHandle = dpcInitParams->hwaHandle;
2908     aoaInitParams.hwaHandle = dpcInitParams->hwaHandle;
2909     cfarInitParams.hwaHandle = dpcInitParams->hwaHandle;
2910     dopplerInitParams.hwaHandle = dpcInitParams->hwaHandle;
2911
2912     for(i = 0; i < RL_MAX_SUBFRAMES; i++)
2913     {
2914         subFrmObj = &objDetObj->subFrameObj[i];
2915
2916         subFrmObj->dpuRangeObj = DPU_RangeProcHWA_init(&rangeInitParams, errCode);
2917
2918         if (*errCode != 0)
2919         {
2920             goto exit;
2921         }
2922
2923         subFrmObj->dpuStaticClutterObj = DPU_StaticClutterProc_init(errCode);
2924
2925         if (*errCode != 0)
2926         {
2927             goto exit;
2928         }
2929
2930         subFrmObj->dpuCFARCAObj = DPU_CFARCAProcHWA_init(&cfarInitParams, errCode);
2931
2932         if (*errCode != 0)
```

DPU Configuration

Recall from DPC Configuration…

- Application calls DPM_ioctl with different message types
- DPM_ioctl internally invokes the DPC's registered ioctl function and passes the message to it

- DPC performs DPU configuration when handling the PRE_START_CFG command
  - The PRE_START_CFG handler calls wrapper functions for each DPU, e.g. DPC_ObjDet_rangeConfig
  - The wrapper allocates the resources required for the DPU and calls the corresponding DPU config function e.g. DPU_RangeProcHWA_config.
- Refer to the call flow below



objectdetection.c (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\datapath\dpc\objectdetection\objdethwa\src) - GVIM

File Edit Tools Syntax Buffers Window Help

```
2737
2738            /* Related to pre-start configuration */
2739            case DPC_OBJDET_IOCTL__STATIC_PRE_START_CFG:
2740            {
2741                DPC_ObjectDetection_PreStartCfg *cfg;
2742                DPC_ObjectDetection_DPC_IOCTL_preStartCfg_memUsage *memUsage;
2743                MemoryP_Stats statsStart;
2744                MemoryP_Stats statsEnd;
2745
2746                /* Pre-start common config must be received before pre-start configs
2763                memUsage->CoreLocalRamTotal = objDetObj->CoreLocalRamObj.cfg.size;
2764                retVal = DPC_ObjDet_preStartConfig(subFrmObj,
2765                            &objDetObj->commonCfg, &cfg->staticCfg, &cfg->dynCfg,
2766                            &objDetObj->edmaHandle[0],
2767                            &objDetObj->L3RamObj,
2768                            &objDetObj->CoreLocalRamObj,
2769                            &objDetObj->hwaMemBankAddr[0],

2232
2233    retVal = DPC_ObjDet_rangeConfig(obj->dpuRangeObj, &obj->staticCfg, &obj->dynCfg,
2234                edmaHandle[DPC_OBJDET_DPU_RANGEPROC_EDMA_INST_ID],
2235                &radarCube, CoreLocalRamObj, &hwaWindowOffset,
2236                &rangeCoreLocalRamScratchUsage, &obj->dpuCfg.rangeCfg);
2237    if (retVal != 0)

1408    hwaCfg->paramSetStartIdx = DPC_OBJDET_DPU_RANGEPROC_PARAMSET_START_IDX;
1409
1410    retVal = DPU_RangeProcHWA_config(dpuHandle, &rangeCfg);
1411    if (retVal != 0)
1412    {
1413        goto exit;
1414    }
1415
1416    /* store configuration for use in intra-sub-frame processing and
1417     * inter-sub-frame switching, although window will need to be regenerated and
1418     * dc range sig should not be reset. */
1419    rangeCfg.staticCfg.resetDcRangeSigMeanBuffer = 0;
1420    *cfgSave = rangeCfg;
1421
```

DPIF: Datapath Interface

Input ADC data

- Property
  - numADCSamples
  - RX interleaved/non-interleaved
  - Complex/Real
- Buffer Pointer

Radar Cube

- Property
  - Layout – RADAR CUBE RANGE DOPPLER RX TX (1)
- Buffer Pointer

Detection Matrix

- Property
  - Layout – DET MATRIX RANGE DOPPLER (1)
- Buffer Pointer

Point cloud

- Property
  - Format – XYZV, RAEV
  - Float

Point Cloud SideInfo

- Property
  - snr
  - noiseVal

dpif_adcdata.h (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\datapath\dpif) - GVIM

File Edit Tools Syntax Buffers Window Help

```
108 /**
109  * @brief
110  *  ADC Data buffer definition
111  *
112  * @details
113  *  The structure defines the ADC data buffer ,including data property, data size and
114  */
115 typedef struct DPIF_ADCBufData_t
116 {
117     /*! @brief  ADCBuf data property */
118     DPIF_ADCBufProperty     dataProperty;
119
120     /*! @brief  ADCBuf  buffer size in bytes */
121     uint32_t                dataSize;
122
123     /*! @brief  ADCBuf data pointer */
124     void                    *data;
125 }DPIF_ADCBufData;
```

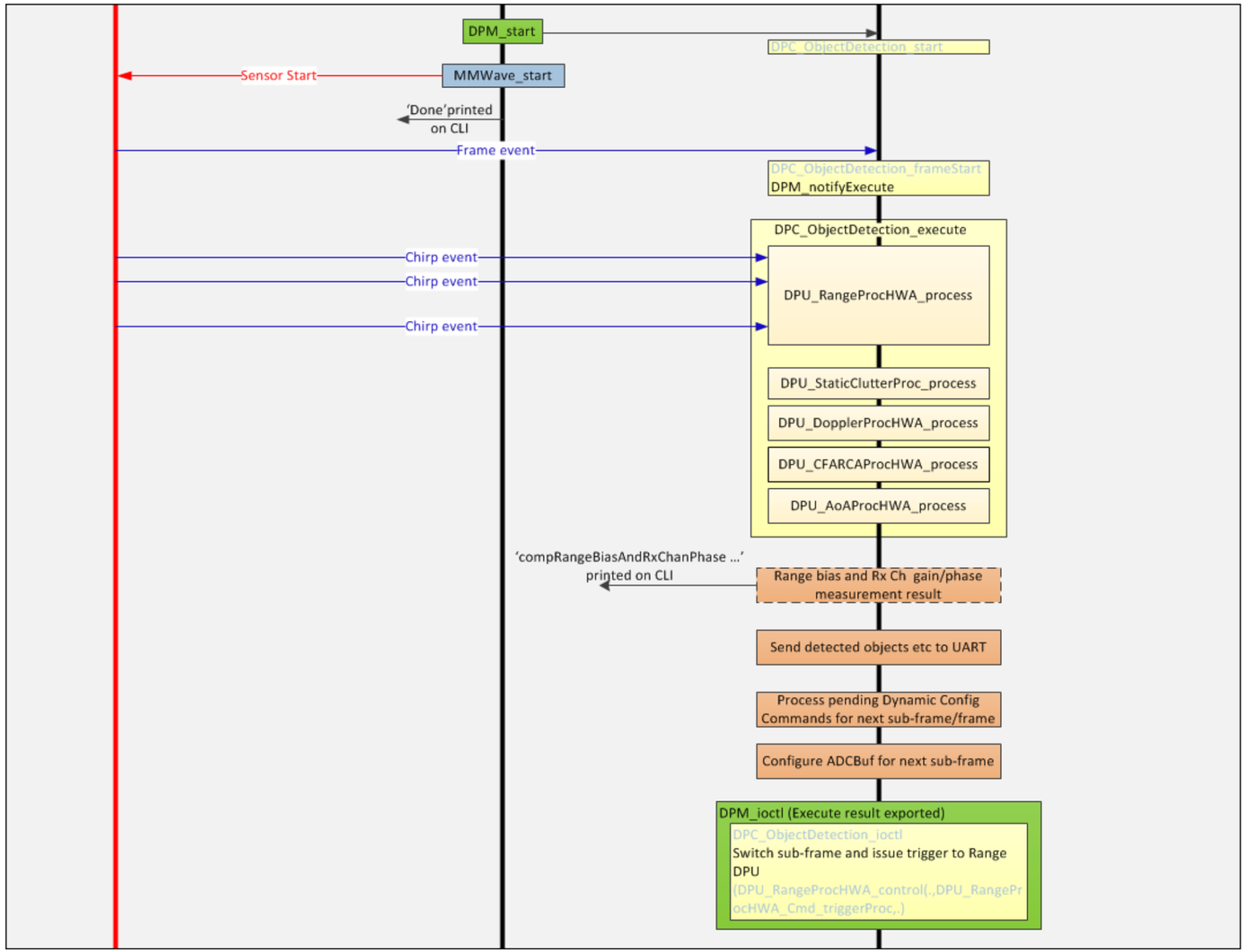
dpif_pointcloud.h (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\datapath\dpif) - GVIM1

File Edit Tools Syntax Buffers Window Help

```
56  *  Point cloud definition in Cartesian coordinate system
57  */
58 typedef struct DPIF_PointCloudCartesian_t
59 {
60     /*! @brief  x - coordinate in meters. This axis is parallel to the sensor plane
61      *          and makes the azimuth plane with y-axis. Positive x-direction is righ
62      *          in the azimuth plane when observed from the sensor towards the scene
63      *          and negative is the opposite direction. */
64     float  x;
65
66     /*! @brief  y - coordinate in meters. This axis is perpendicular to the
67      *          sensor plane with positive direction from the sensor towards the scen
68     float  y;
69
70     /*! @brief  z - coordinate in meters. This axis is parallel to the sensor plane
71      *          and makes the elevation plane with the y-axis. Positive z direction
72      *          is above the sensor and negative below the sensor */
73     float  z;
74
75     /*! @brief  Doppler velocity estimate in m/s. Positive velocity means target
76      *          is moving away from the sensor and negative velocity means target
77      *          is moving towards the sensor. */
78     float    velocity;
79 }DPIF_PointCloudCartesian;
```

Datapath Execution – Runtime View

- **At sensor start:** Application calls DPM_start which calls the DPC's pre-registered start function DPC_ObjectDetection_start.
  - The mmw demo does this in the sensorStart CLI command handler function.
- **At every frame interrupt:** The DPC's pre-registered frame start call back function, DPC_ObjectDetection_frameStart is invoked.
  - **Recall from DPC_init:** The DPC's frameStart callback is registered with the DPM during DPC initialization
- This invokes the DPC's registered execute function, e.g. DPC_ObjectDetection_execute
  - **Under the hood:** The Frame Start handler calls DPM_notifyExecute which posts the semaphore for DPM_execute
  - DPM_execute then calls the DPC's pre-registered execute function.
- DPC_ObjectDetection_execute performs the frame processing and populates the output in DPC_ObjectDetection_ExecuteResult structure and returns.
- Application reads the output structure and sends it over UART. This completes the frame processing.



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main.c (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\demo\xwr64xx\mmw) - GVIM1

File Edit Tools Syntax Buffers Window Help

```
1223  *       mmw demo helper Function to start sensor.
1224  *
1225  *  @retval  0 if no error, -1 if error
1226  */
1227 int32_t MmwDemo_startSensor(void)
1228 {
1229     int32_t     errCode;
1230     MMWave_CalibrationCfg   calibrationCfg;
1231
1232     /**************************************************************************
1233      * Data path :: start data path first - this will pend for DPC to ack
1234      **************************************************************************/
1235     MmwDemo_dataPathStart();
```

main.c (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\demo\xwr64xx\mmw) - GVIM

File Edit Tools Syntax Buffers Window Help

```
1786 void MmwDemo_dataPathStart (void)
1787 {
1788     int32_t errCode;
1789
1790     DebugP_log0("App: Issuing DPM_start\n");
1791
1792     /* Configure HW LVDS stream for the first sub-frame that will start upon
1793      * start of frame */
1794     if (gMmwMCB.subFrameCfg[0].lvdsStreamCfg.dataFmt != MMW_DEMO_LVDS_STREAM_CFG_DAT
1795     {
1796         MmwDemo_configLVDSHwData(0);
1797     }
1798
1799     /* Start the DPM Profile: */
1800     if ((errCode = DPM_start(gMmwMCB.dataPathObj.objDetDpmHandle)) < 0)
1801     {
```

Datapath Execution – Runtime View

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objectdetection.c (C:\ti\mmwave_sdk_03_04_00_03\packa...ti\datapath\dpc\objectdetection\objdethwa\src) - GVIM1

File Edit Tools Syntax Buffers Window Help

```
417  */
418 static void DPC_ObjectDetection_frameStart (DPM_DPCHandle handle)
419 {
420     ObjDetObj     *objDetObj = (ObjDetObj *) handle;
421
422     objDetObj->stats.frameStartTimeStamp = Cycleprofiler_getTimeStamp();
423
424     DebugP_log2("ObjDet DPC: Frame Start, frameIndx = %d, subFrameIndx = %d\n",
425                 objDetObj->stats.frameStartIntCounter, objDetObj->subFrameIndx);
426
427     /* Check if previous frame (sub-frame) processing has completed */
428     DPC_Objdet_Assert(objDetObj->dpmHandle, (objDetObj->interSubFrameProcToken == 0)
429     objDetObj->interSubFrameProcToken++;
430
431     /* Increment interrupt counter for debugging and reporting purpose */
432     if (objDetObj->subFrameIndx == 0)
433     {
```

objectdetection.c (C:\ti\mmwave_sdk_03_04_00_03\packa...ti\datapath\dpc\objectdetection\objdethwa\src) - GVIM1

File Edit Tools Syntax Buffers Window Help

```
832  *  @retval
833  *      Error    -    <0
834  */
835 int32_t DPC_ObjectDetection_execute
836 (
837     DPM_DPCHandle   handle,
838     DPM_Buffer*     ptrResult
839 )
840 {
841     ObjDetObj   *objDetObj;
842     SubFrameObj *subFrmObj;
843     DPU_RangeProcHWA_OutParams outRangeProc;
844     DPU_StaticClutterProc_OutParams outStaticClutter;
845     DPU_DopplerProcHWA_OutParams outDopplerProc;
846     DPU_CFARCAProcHWA_OutParams outCfarcaProc;
847     DPU_AoAProcHWA_OutParams outAoaProc;
848     int32_t retVal;
849     DPC_ObjectDetection_ExecuteResult *result;
850     DPC_ObjectDetection_ProcessCallBackCfg *processCallBack;
851     int32_t i;
852
```

Datapath Execution – Runtime View

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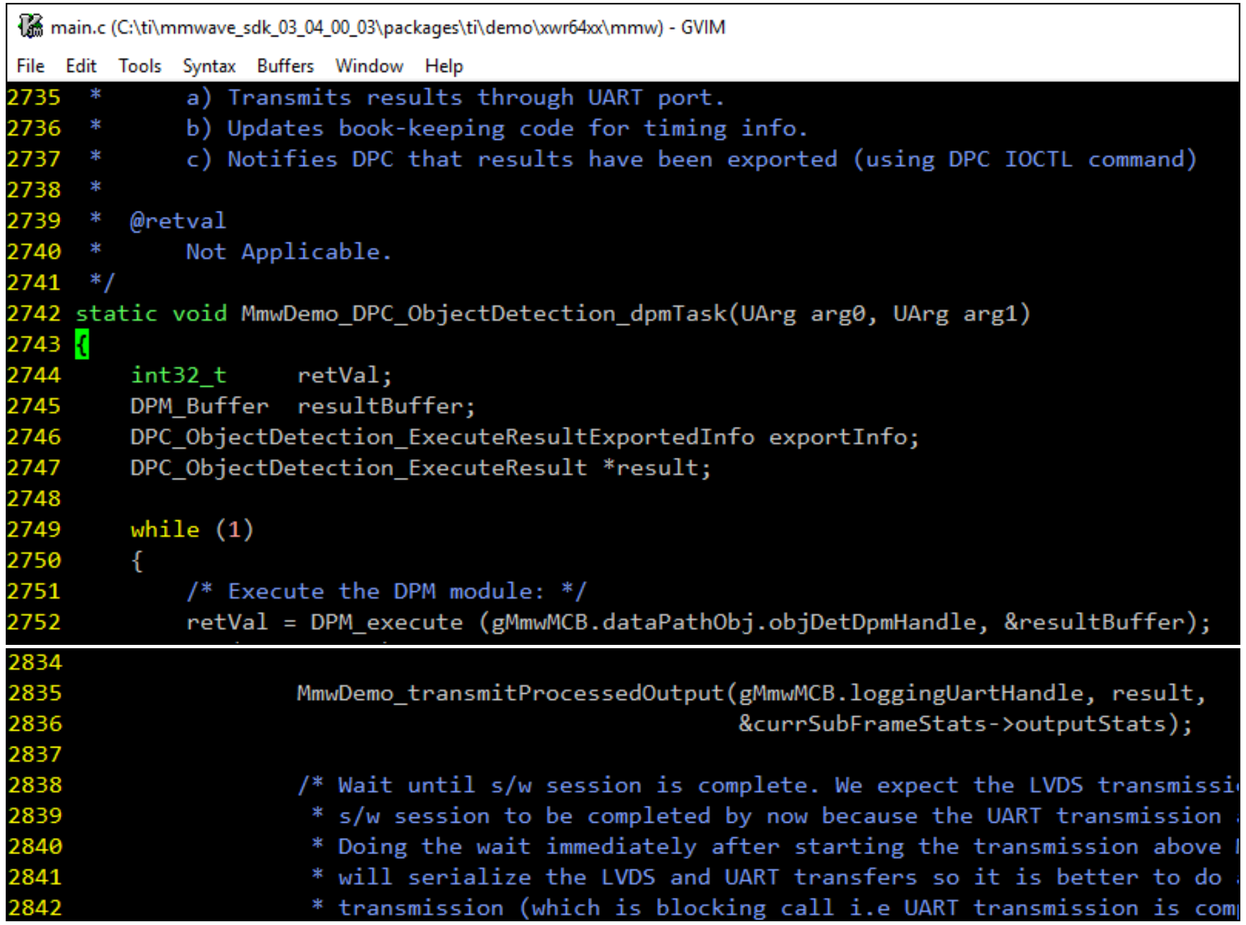

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main.c (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\demo\xwr64xx\mmw) - GVIM

File Edit Tools Syntax Buffers Window Help

```
2174 */
2175 void MmwDemo_transmitProcessedOutput(UART_Handle uartHandle,
2176                                      DPC_ObjectDetection_ExecuteResult *result,
2177                                      MmwDemo_output_message_stats      *timingInfo)
2178 {
2179     MmwDemo_output_message_header header;
2180     MmwDemo_GuiMonSel   *pGuiMonSel;
2181     MmwDemo_SubFrameCfg *subFrameCfg;
2182     uint32_t tlvIdx = 0;
2183     uint32_t i;
2184     uint32_t numPaddingBytes;
2185     uint32_t packetLen;
2186     uint8_t padding[MMWDEMO_OUTPUT_MSG_SEGMENT_LEN];
2187     uint16_t *detMatrix = (uint16_t *)result->detMatrix.data;
2188
2189     MmwDemo_output_message_tl   tl[MMWDEMO_OUTPUT_MSG_MAX];
```

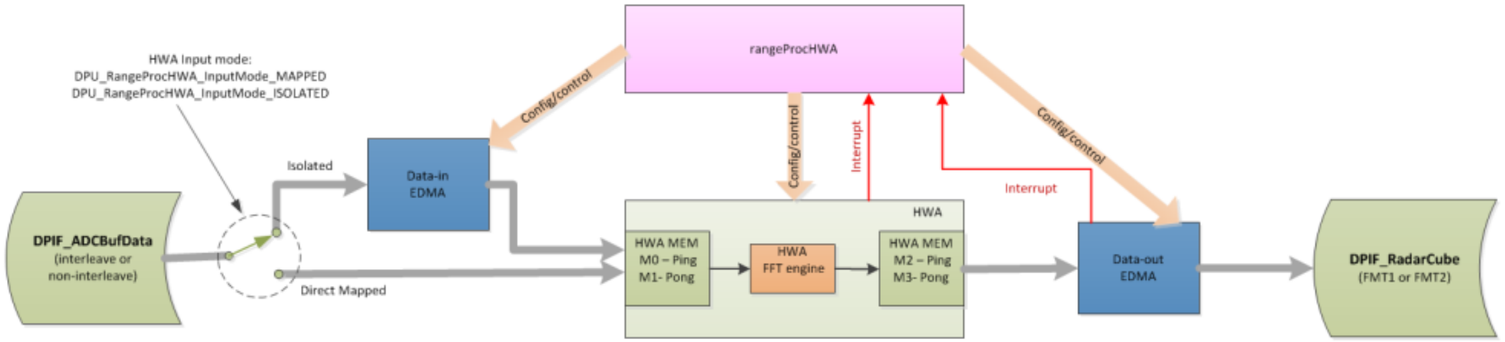
```
2287     tlvIdx = 0;
2288     /* Send detected Objects */
2289     if ((pGuiMonSel->detectedObjects == 1) || (pGuiMonSel->detectedObjects == 2) &&
2290         (result->numObjOut > 0))
2291     {
2292         UART_writePolling (uartHandle,
2293                            (uint8_t*)&tl[tlvIdx],
2294                            sizeof(MmwDemo_output_message_tl));
2295
2296         /*Send array of objects */
2297         UART_writePolling (uartHandle, (uint8_t*)result->objOut,
2298                            sizeof(DPIF_PointCloudCartesian) * result->numObjOut);
2299         tlvIdx++;
2300     }
2301
2302     /* Send detected Objects Side Info */
```

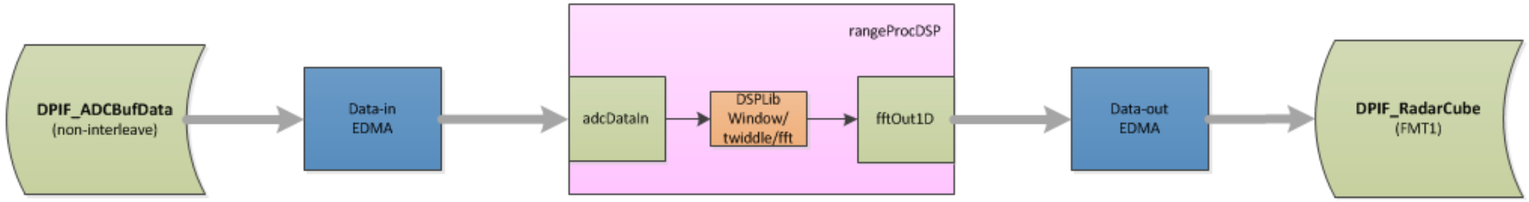
DPUs and DPCs in SDK 3.x

RangeProc DPU

- Purpose: (1D FFT+ DC Range Calib) processing during active frame.
  - Takes ADCBuf as input
    - interleaved or nonInterleaved format
    - Single chirp or multichirp (DSP mode only)
    - Either direct access (HWA mode only) or via EDMA
  - Produces RadarCube in L3 in user requested format (fixed set of formats described in data interface).
  - Performs FFT using HWA or DSP based on configuration.
  - Performs DC range calibration either inline (DSP mode) or at the end of all chirps (HWA mode).

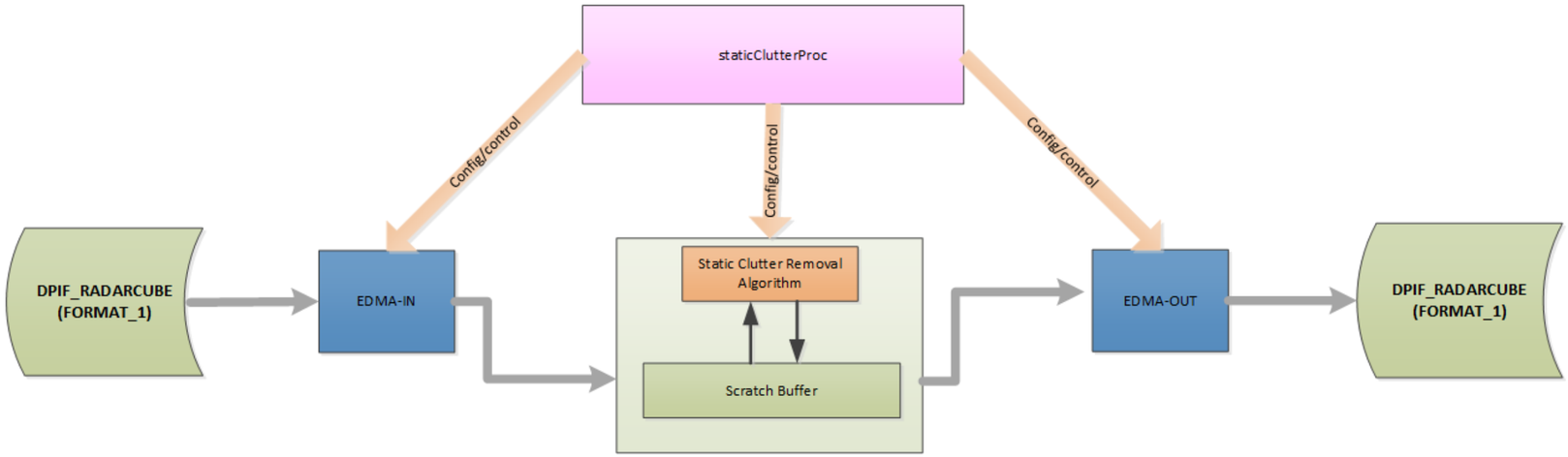
- Supported architecture
  - R4F, C674x
  - Different files for HWA based and S/W based implementation





Static Clutter DPU

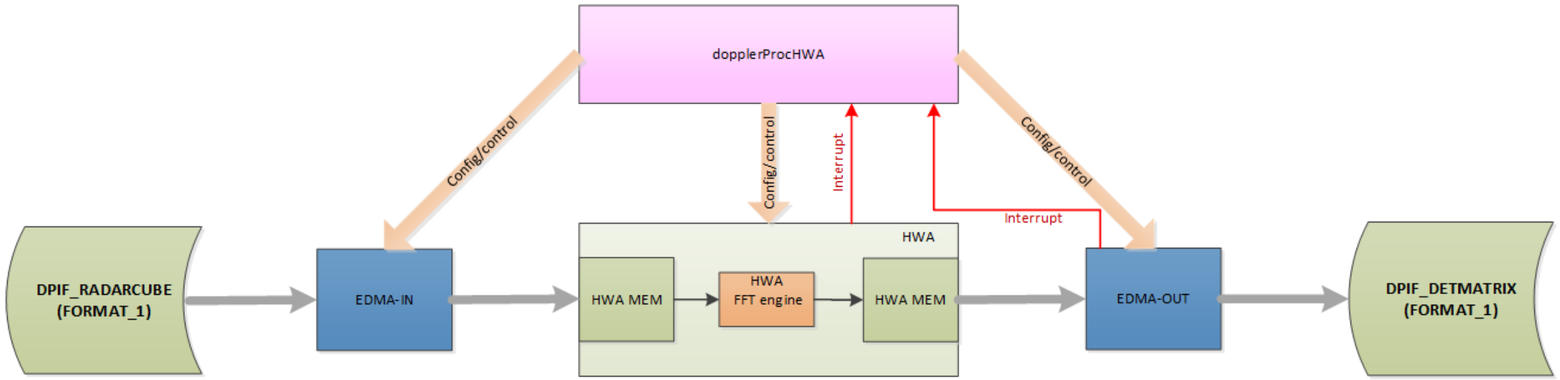
- Purpose: (Clutter Removal) processing during inter frame.
  - Takes non-transposed formatted 1DOUT Radarcube as input
  - Updates the RadarCube in L3 (keeping the same format)
  - S/W based only



- Supported architecture
  - R4F, C674x

Doppler DPU

- Purpose: (2D FFT + Energy Sum) processing during inter frame.
  - Takes non-transposed formatted 1DOUT Radarcube as input
  - Produces Detection Matrix in L3 in fixed format
  - Performs FFT and Energy Sum using H/W(HWA)
    - S/W(DSP) based implementation would be added in the SDK in future.

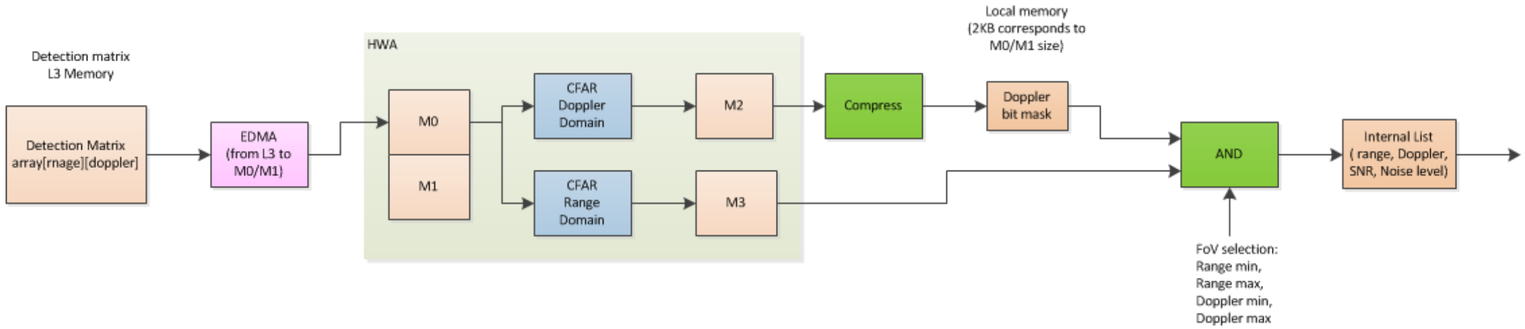


- Supported architecture
  - R4F, C674x

CFAR-CA DPU

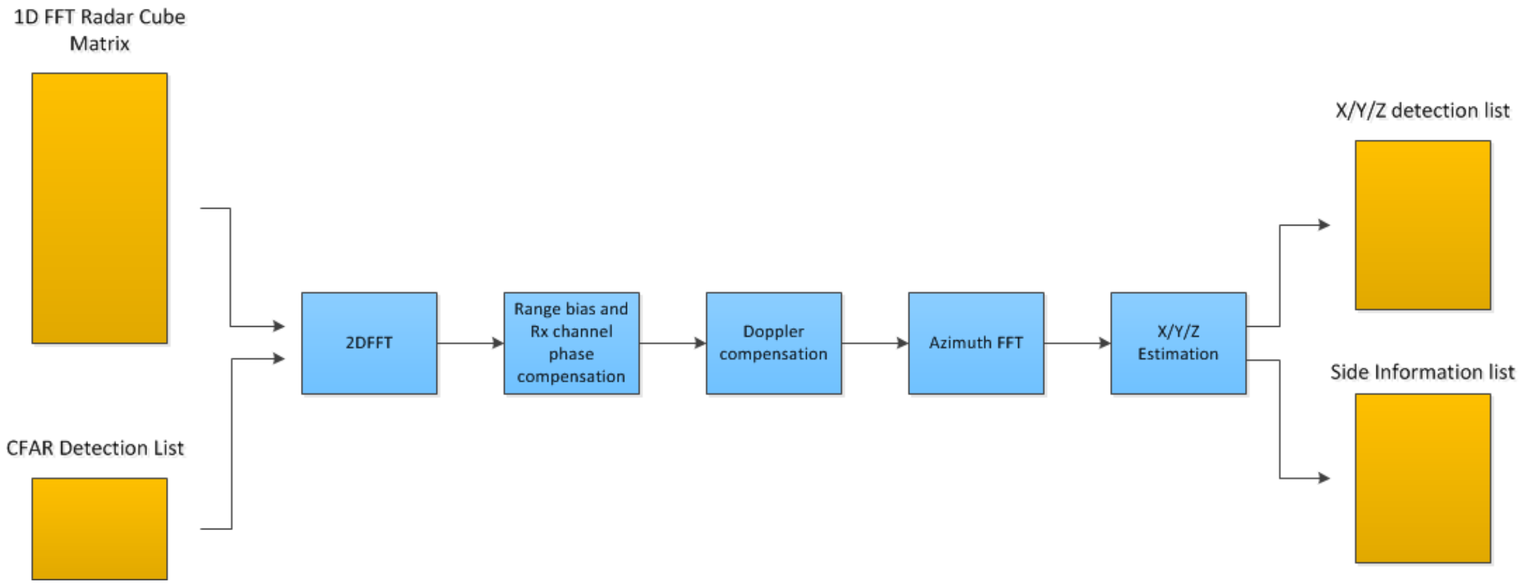
- Purpose: (CFAR-CA +peak grouping) processing during inter frame.
  - User can choose between various CFAR-CA implementation: CFAR-CA, CFAR-CASO, CFAR-CAGO
  - Fixed Point implementation
  - 2 pass implementation: first pass (optional) in Doppler direction and then second pass in Range direction
  - Performs CFAR and PeakGrouping using H/W(HWA)
    - S/W(DSP) based implementation would be added in SDK in future
  - Takes Detection Matrix as input
  - Produces bitmask of peaks and SNR information for AoA.

- Supported architecture
  - R4F, C674x



AoA DPU

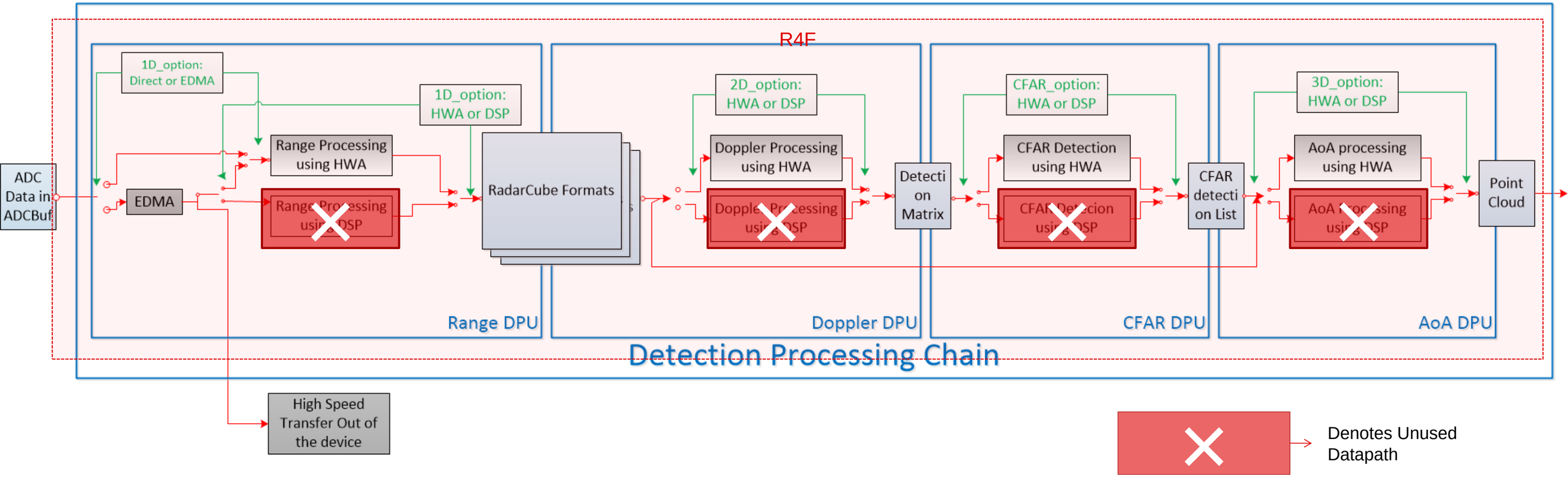
- Purpose: (Range/Phase/Doppler compensation + *Near field correction* + *Max Velocity enhancement* + AoA + FoV filter) processing during inter frame.
  - Takes non-transposed formatted 1DOUT Radarcube, detection matrix and peak bitmask as input
  - Produces Point Cloud
  - Performs any FFT ops using H/W(HWA)
    - S/W(DSP) based implementation will be added in SDK in future
  - All other processing operations are done using S/W.
    - For R4F based implementation, near field and max velocity algos will not be offered
  - All the processing ops other than AoA FFT is optional and driven by user input



- Supported architecture
  - R4F, C674x

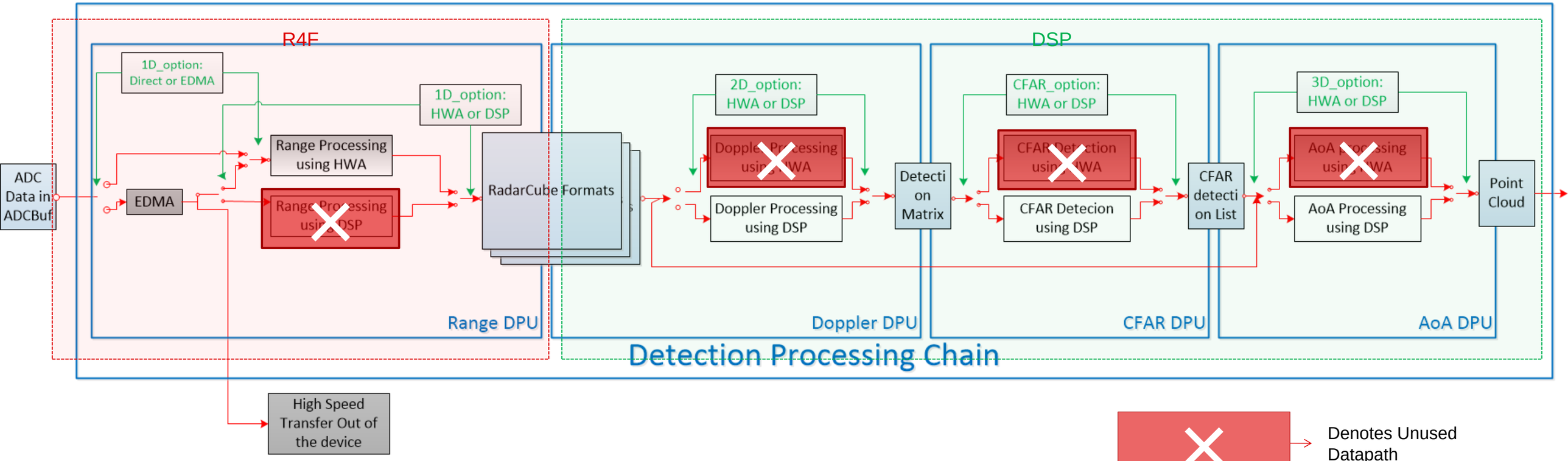
xWR64xx OOB Demo Chain (DPC)

- Detection Processing Chain (DPC) for **xWR64xx** Out of Box demo.
- Demonstrates Radar Signal Processing using Cortex R4F + HWA
- Also runs on **xWR68xx** (C674x DSP not used)

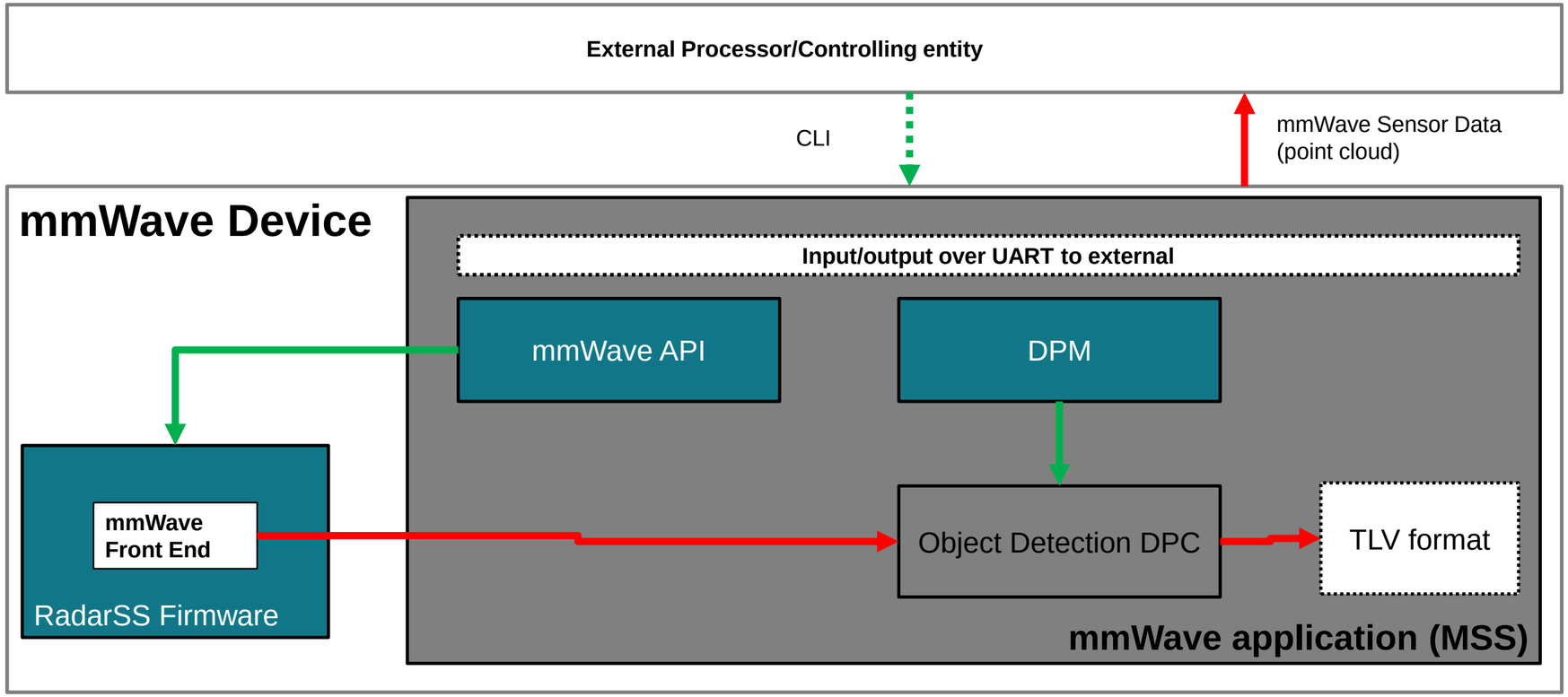


xWR68xx OOB Demo Chain (DPC)

- Detection Processing Chain (DPC) for **xWR68xx** Out of Box demo.
- Demonstrates Radar Signal Processing using Cortex R4F + HWA + C674x DSP
- DSP provides higher performance and frees up R4F for other processing (e.g. Object Tracking)



68xx OOB Demo - Application View



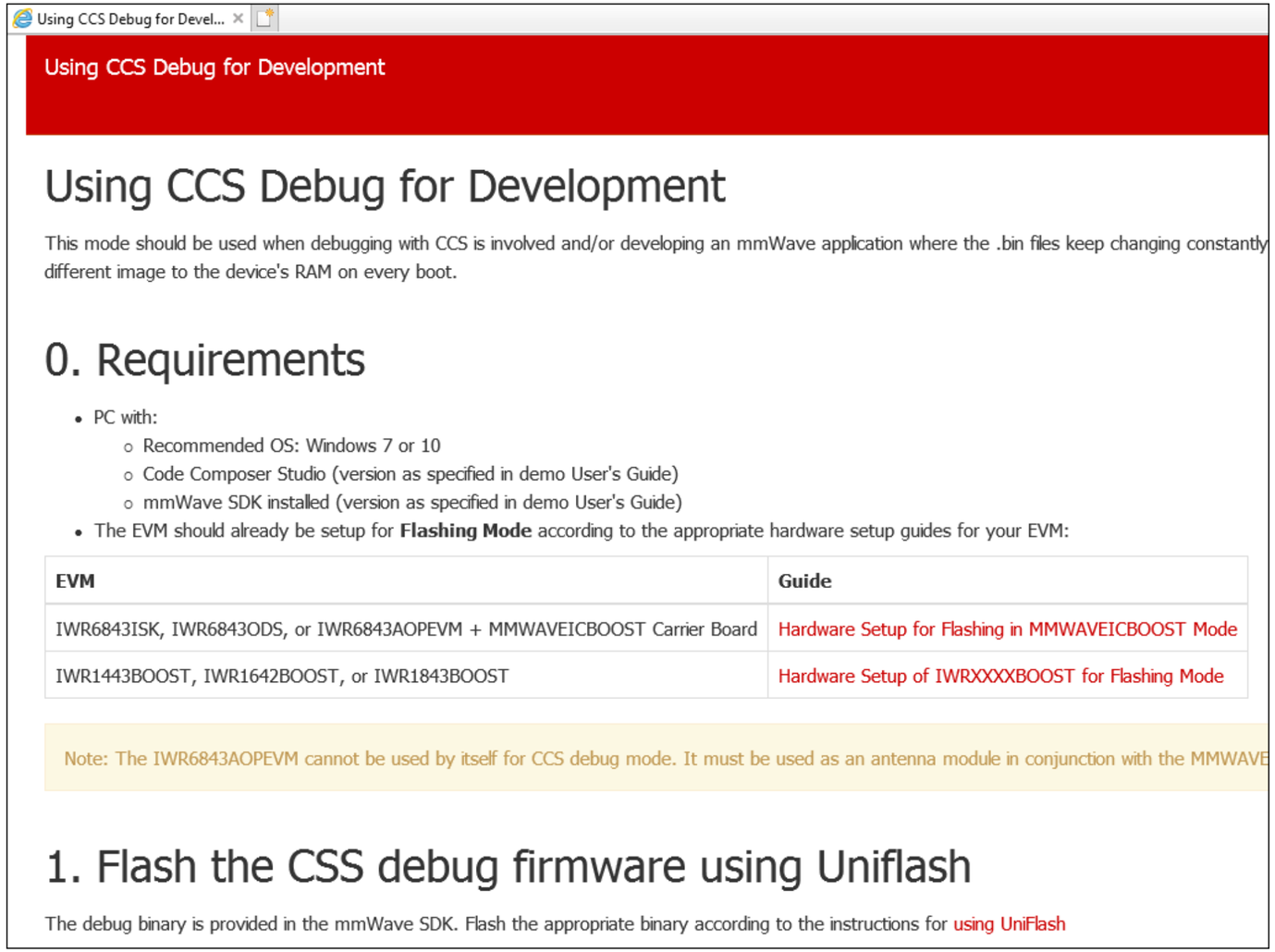
Software Development and Debugging

Software Development Resources

- **Software Development Resources:** The following resources are key to learning about software development for TI processors.
  - **BIOS users guide**: Installed as part of MMWAVE-SDK, it is available in the TI install directory e.g. C:\ti\bios_6_73_01_01\docs\Bios_User_Guide.pdf.
    - This is the one of the best resources for learning about SYSBIOS and software development for TI processors.
  - **Linker command files:** Understanding these is fundamental to developing applications for TI RTOS (SYSBIOS). Refer to the following resources:
    - TI Linker Command File Primer
    - Advanced Linker Techniques for Convenient and Efficient Memory Usage
- **Other helpful resources**
  - Getting Started with Code Composer Studio v7
  - Debugging Common Application Issues with TI-RTOS
  - TI-RTOS Workshop
  - Introduction to C6000 Architecture
  - C6000 Cache - Overview (7 of 15)
  - Using C6000 EDMA3 - Part 1 (13 of 15)

MMWAVE-SDK Debugging

- **Pre-requisites:** The user should be familiar with general CCS debugging techniques e.g. running code in CCS, putting breakpoints, observing the values of variables and memories etc. Following resources can be used to ramp-up on these topics if needed.
  - Getting Started with Code Composer Studio v7
  - Debugging Common Application Issues with TI-RTOS
- In addition to the above, the user must be familiar with basic procedures for running an MMWAVE application in CCS debug mode. This is explained in the mmWave Industrial Toolbox at the following page:
  - Using CCS Debug for Development


Using CCS Debug for Devel...

Using CCS Debug for Development

Using CCS Debug for Development

This mode should be used when debugging with CCS is involved and/or developing an mmWave application where the .bin files keep changing constantly different image to the device's RAM on every boot.

0. Requirements

- PC with:
  - Recommended OS: Windows 7 or 10
  - Code Composer Studio (version as specified in demo User's Guide)
  - mmWave SDK installed (version as specified in demo User's Guide)
- The EVM should already be setup for **Flashing Mode** according to the appropriate hardware setup guides for your EVM:

EVM	Guide
IWR6843ISK, IWR6843ODS, or IWR6843AOPEVM + MMWAVEICBOOST Carrier Board	Hardware Setup for Flashing in MMWAVEICBOOST Mode
IWR1443BOOST, IWR1642BOOST, or IWR1843BOOST	Hardware Setup of IWRXXXXBOOST for Flashing Mode

Note: The IWR6843AOPEVM cannot be used by itself for CCS debug mode. It must be used as an antenna module in conjunction with the MMWAVE

1. Flash the CSS debug firmware using Uniflash

The debug binary is provided in the mmWave SDK. Flash the appropriate binary according to the instructions for using UniFlash

MMWAVE-SDK Debugging

- **Rebuilding SDK code for debug:**
  - All MMWAVE-SDK code (drivers, OOB demo application and DPU libs) is built with –O3 optimization, which does not allow single step debugging in the corresponding components.
  - In order to enable step debugging in CCS, the –O3 optimization options needs to be removed (or changed to a lower level)
    - Remove the –O3 flag in the SDK common makefile from R4F_CFLAGS and/or C674_CFLAGS directives to change build options for ARM and/or DSP code.
    - Re-build the demo and the desired pre-compiled libs (e.g. drivers, DPUs) separately with the non-optimized configuration to enable debugging.
- **A note about DPUs:** All DPUs are linked with the application as pre-compiled libs, so just re-building the application/demo code does not re-build the DPU libs automatically. Any DPUs that need to be debugged, should be re-built first with the new build options and then the applications code re-compiled to link with the new DPU lib(s). This applies to the SDK drivers as well.
- Removing optimization may increase the memory requirements and/or break real-time behavior.

SDK Compile flags for Cortex R4F core

mmwave_sdk.mak (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\common) - GVIM

File Edit Tools Syntax Buffers Window Help

```
111 # Compiler flags used for the R4 Builds:
112 R4F_CFLAGS   = -mv7R4 --code_state=16 --float_support=VFPv3D16 --abi=eabi -me
113                --define=SUBSYS_MSS --define=$(PLATFORM_DEFINE)
114                --define=_LITTLE_ENDIAN --define=DebugP_ASSERT_ENABLED $(R4F_INCLUDE)
115                -g -O3 -display_error_number --diag_warning=225 --diag_wrap=off
116                --little_endian --preproc_with_compile --gen_func_subsections
117                            --emit_warnings_as_errors $(R4F_CFLAGS_ENUM_TYPE)
118
```

SDK Compile flags for C674x DSP core

mmwave_sdk.mak (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\common) - GVIM

File Edit Tools Syntax Buffers Window Help

```
207 C674_INCLUDE = -i$(MMWAVE_SDK_INSTALL_PATH) -i$(C674_CODEGEN_INSTALL_PATH)/include $(
208
209 # Compiler Flags for C674 Builds:
210 C674_CFLAGS   = -mv6740 --abi=eabi --gcc -g -O3 -mf3 -mo --define=SUBSYS_DSS
211                 --define=$(PLATFORM_DEFINE) --define=_LITTLE_ENDIAN --display_error_nu
212                 --define=DebugP_ASSERT_ENABLED --diag_warning=225 --diag_wrap=off
213                 --preproc_with_compile $(C674_INCLUDE) --emit_warnings_as_errors
214
```

MMWAVE-SDK Debugging

- **Disabling Real time asserts:**
  - If the DPC cannot complete the frame (or sub-frame) processing within the real-time deadline, it raises as assert causing the application to exit
  - When step debugging a distributed DPC which runs on both R4F and DSP cores (e.g. in the 68xx point cloud detection chain), this assert should be disabled on both cores in DPC code as shown otherwise application would crash as shown in this CCS console log.
  - NOTE: Make sure to re-enable the frame timing assert when running the DPC in non debug mode.

objectdetection.c (C:\ti\mmwave_sdk_03_04_00_03\packages\ti\datapath\dpc\objectdetection\objdethwa\src) - GVIM

File Edit Tools Syntax Buffers Window Help

```
418 static void DPC_ObjectDetection_frameStart (DPM_DPCHandle handle)
419 {
420     ObjDetObj      *objDetObj = (ObjDetObj *) handle;
421
422     objDetObj->stats.frameStartTimeStamp = Cycleprofiler_getTimeStamp();
423
424     DebugP_log2("ObjDet DPC: Frame Start, frameIndx = %d, subFrameIndx = %d\n",
425                 objDetObj->stats.frameStartIntCounter, objDetObj->subFrameIndx);
426
427     /* Check if previous frame (sub-frame) processing has completed */
428     DPC_Objdet_Assert(objDetObj->dpmHandle, (objDetObj->interSubFrameProcToken == 0)
429     objDetObj->interSubFrameProcToken++;
430
```

Console

iwr6843.ccxml:CIO

```
[Cortex_R4_0] ********************************************
Debug: Launching the MMW Demo on MSS
********************************************
Debug: Launched the Initialization Task
Debug: mmWave Control Initialization was successful
Debug: mmWave Control Synchronization was successful
[C674X_0] Debug: DPM Module Sync is done
[Cortex_R4_0] Debug: CLI is operational
Debug: Sending rlRfSetLdoBypassConfig with 0 0 0
============ Heap Memory Stats ============
                           Size         Used         Free      DPCUsed
   System Heap(TCMB)        32768        25840         6928         2048
                 L3       786432       131072       655360
     localRam(TCMB)         4096          512         3584
============ Heap Memory Stats ============
                           Size         Used         Free      DPCUsed
    System Heap(L2)        32768        16104        16664            0
                 L3       786432         8192       778240
       localRam(L2)        50176        15016        35160
       localRam(L1)        16384         5632        10752
Starting Sensor (issuing MMWave_start)
{module#9}: "../objdetrangehwa.c", line 640: error {id:0x10000, args:[0x1a19c, 0x1a19c]}
xdc.runtime.Error.raise: terminating execution
```

Understanding Error Codes: Datapath Errors

- When demo runs into error conditions, an error code is generated and printed out on CCS console
- The error code is a negative integer e.g. shown in the picture.
- Can be from various sources such as Drivers, Control modules, DPC, DPU or demo (i.e. application)
- Error code defined as: (**Module error code base** minus **Module specific error code**)
  - The module error code base values are defined in **packages\ti\common\mmwave_error.h.**
  - The base error codes for DPC and DPU are define in **packages\ti\datapath\dpif\dp_error.h**
  - Individual DPU specific error codes defined in the DPU header files
- **Example:** Parsing the error -30430 shown here
  - The error code is from module with error base "-30000", which indicates it is DPU error
  - Referring to dp_error.h, base "-30400" is from AOA Proc.
  - Then find the error code in aoaprocdsp.h for error(-30) which is DPU_AOAPROCDSP_ESCRATCHSIZE
- **NOTE:** In SDK demos, these error codes are not sent out on UART so the demo must be run in CCS debug mode to get the error code
- Refer to SDK module documentation at the following location (in the SDK install directory) for more details:
  - file:///C:/ti/mmwave_sdk_03_05_00_04/packages/ti/demo/xwr68xx/mmw/docs/doxygen/html/index.html#mmwave_error

Datapath Errors

```
Debug: mmWave Control Initialization was successful
Debug: mmWave Control Synchronization was successful
Debug: Sending rlRfSetLdoBypassConfig with 3 1 0
Debug: Init Calibration Status = 0xffe
Azimuth Tx: 1 (MIMO:0), Elev Tx:0
Ant setting virtualAzim: 4 , virtual Elev :0
chirpThreshold 1 max = 64,
Error: DPM Report 4 received with error:-30430 arg0:0x64 arg1:0x80050e
{module#9}: "src/mss/mss_main.c", line 1391: error {id:0x10000, args:[
xdc.runtime.Error.raise: terminating execution
```

-30430 = -30000 -400 -30

```
mmwave_error.h (C:\ti\mmwave_sdk_03_05_00_04\packages\ti\common) - GVIM
File  Edit  Tools  Syntax  Buffers  Window  Help
 * Base Error Code for the mmWave data path (-30000 - -59999)
 ************************************************************
#define MMWAVE_ERRNO_DPU_BASE                (-30000)
#define MMWAVE_ERRNO_DPC_BASE                (-40000)
#define MMWAVE_ERRNO_DEMO_BASE               (-50000)

#ifdef __cplusplus
}
#endif
```

-30000 = DPU Error base

```
dp_error.h (C:\ti\mmwave_sdk_03_05_00_04\packages\ti\datapath\dpif) - GVIM1
File  Edit  Tools  Syntax  Buffers  Window  Help
#define DP_ERRNO_RANGE_PROC_BASE                    (MMWAVE_ERRNO_DPU_BASE -100)
#define DP_ERRNO_DOPPLER_PROC_BASE                  (MMWAVE_ERRNO_DPU_BASE -200)
#define DP_ERRNO_CFARCA_PROC_BASE                   (MMWAVE_ERRNO_DPU_BASE -300)
#define DP_ERRNO_AOA_PROC_BASE                      (MMWAVE_ERRNO_DPU_BASE -400)
#define DP_ERRNO_STATIC_CLUTTER_PROC_BASE           (MMWAVE_ERRNO_DPU_BASE -500)
#define DP_ERRNO_DDMA_BASE                          (MMWAVE_ERRNO_DPU_BASE -600)

```

-400 = AOA Proc Error base

```
aoaprocdsp.h (C:\ti\mmwave_sdk_03_05_00_04\packages\ti\datapath\dpc\dpu\aoaproc) - GVIM2
File  Edit  Tools  Syntax  Buffers  Window  Help
/**
 * @brief   Error Code: One of the provided scratch buffers has insufficient size
 */
#define DPU_AOAPROCDSP_ESCRATCHSIZE             (DP_ERRNO_AOA_PROC_BASE-30)

/**
```

-30 = Insufficient Memory Error

Understanding Error Codes: mmWave Errors

- Besides Datapath errors, there is another class of errors known as mmWave module errors.
- These represent errors returned by the RF Front-End e.g. incorrect profile configuration.
- Defined as a combination of mmWave error, Susbsystem error and error level as shown.
  - mmwave errors defined in **packages\ti\control\mmwave\mmwave.h**
  - Subsystem errors defined in **packages\ti\control\mmwavelink for mmwavelink.h**
  - Error level represents WARNING or ERROR.
- **Example:** The error shown in the log here indicates
  - The error is from module(-3100 i.e. mmwave) with error -8 (MMWAVE_EPROFILECFG)
  - The Subsystem (mmwavelink) error is 36 which is defined as RL_RET_CODE_PF_START_FREQ_INVAL_IN in mmwavelink.h, which indicates invalid start frequency specified in ProfileCfg API.

mmWave Link errors

```
Console
iwr6843.ccxml:CIO
[Cortex_R4_0] ******************************************
Debug: Launching the MMW Demo on MSS
******************************************
Debug: Launched the Initialization Task
Debug: mmWave Control Initialization was successful
Debug: mmWave Control Synchronization was successful
[C674X_0] Debug: DPM Module Sync is done
[Cortex_R4_0] Debug: CLI is operational
Debug: Sending rlRfSetLdoBypassConfig with 0 0 0
Error: mmWave Config failed [Error code: -3108 Subsystem: 36]
```

Bits(31::16)	Bits(15::2)	Bits (1::0)
mmwave error	Subsystem error	error level

mmwave_error.h (C:\ti\mmwave_sdk_03_05_00_04\packages\ti\common) - GVIM3

File Edit Tools Syntax Buffers Window Help

```
60 #define MMWAVE_ERRNO_EDMA_BASE                (-3000)
61 #define MMWAVE_ERRNO_BASE                     (-3100)
62 #define MMWAVE_ERRNO_CSI_BASE                 (-3200)
```

mmwave.h (C:\ti\mmwave_sdk_03_05_00_04\packages\ti\control\mmwave) - GVIM3

File Edit Tools Syntax Buffers Window Help

```
148  */
149 #define MMWAVE_EPROFILECFG                    (MMWAVE_ERRNO_BASE-8)
150
151 /**
152  * @brief   Error Code: mmWave link chirp configuration failed
153  */
154 #define MMWAVE_ECHIRPCFG                      (MMWAVE_ERRNO_BASE-9)
```

mmwavelink.h (C:\ti\mmwave_sdk_03_05_00_04\packages\ti\control\mmwavelink) - GVIM3

File Edit Tools Syntax Buffers Window Help

```
441 /*! Profile config API */
442 #define RL_RET_CODE_PF_IND_INVAL_IN           (35U) /* PF indx >= 4 */
443 #define RL_RET_CODE_PF_START_FREQ_INVAL_IN    (36U) /* PF freq const is not
444                                                        with[76GHz,81GHz] in limit */
445 #define RL_RET_CODE_PF_IDLE_TIME_INVAL_IN     (37U) /* PF idle time const > 5.24ms */
446 #define RL_RET_CODE_PF_IDLE_TIME_1INVAL_IN    (38U) /* Maximum DFE spill time (refer
```

Extending SDK architecture for advanced applications

Developing a Custom Radar Processing Chain

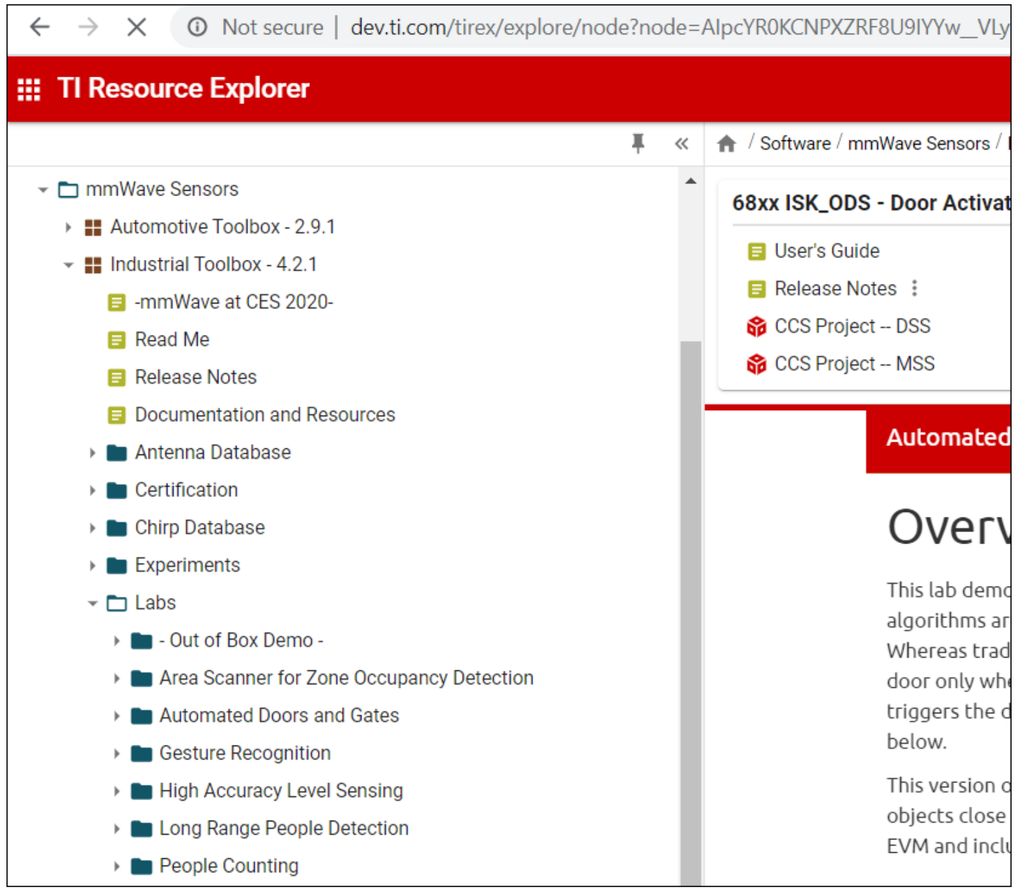
Key considerations for developing a custom mmWave processing chain with SDK 3.x architecture

- Understand the data processing chain for the target application and model it in terms of DPC and DPUs
- Re-use the SDK Out of Box Detection Processing **OR** develop a new Detection Chain
  - SDK Out of box DPC is a Range-Doppler based processing chain.
  - Lower angular resolution as compared to Range-Azimuth (Capon Beamforming) chain
    - SDK Detection Chain re-used for Long Range People Detection and Area Scanner Demos
    - But a Higher resolution Capon Beamforming Detection Chain was developed for Indoor People Counting Demos
  - Range Processing is still re-used irrespective of the rest of the Detection Processing
- Additional processing requirements beyond the OOB point cloud detection
  - Can the additional processing be added to an existing DPU or do we need to create a new DPU
    - Object Tracking - new DPU
    - Static Object Detection - new DPU
    - 2D AoA (Angle of Arrival) using DSP – Enhancement to existing AoA DPU
- Enhancements needed at the DPC and Application level e.g.
  - Tracking
  - Beam-steering
  - Static object detection
- Memory and MIPS requirements for the additional processing

Examples of Custom DPUs and DPCs

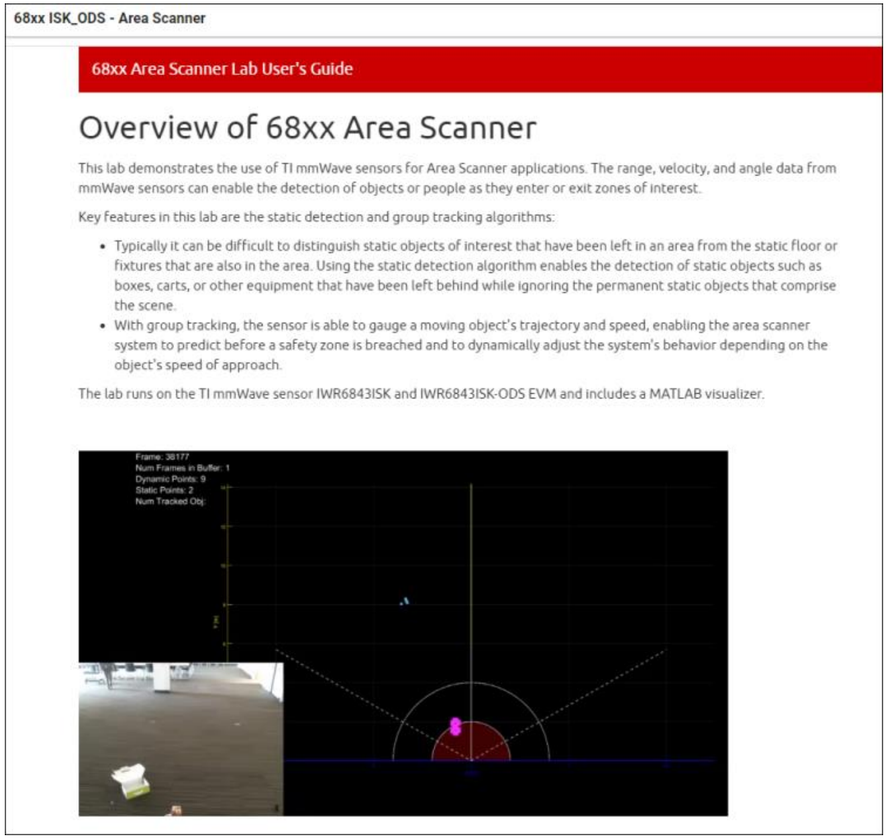
New DPUs and DPCs developed in mmWave Industrial Toolbox

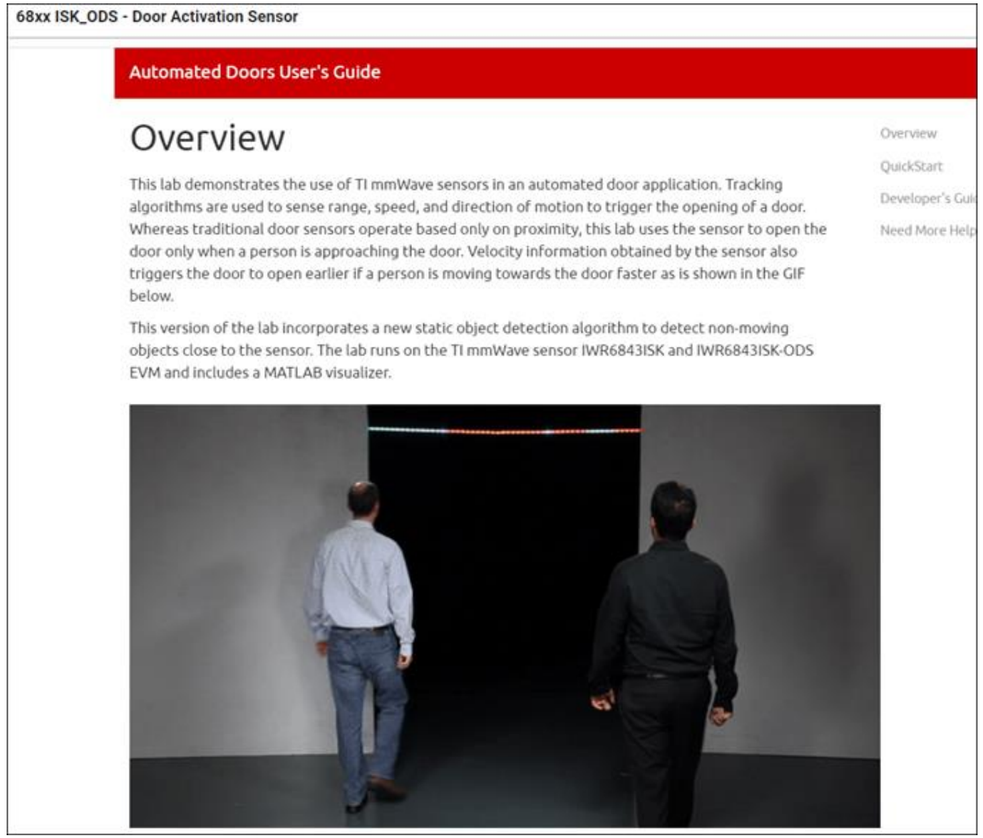
- TrackerProc DPU and ObjectDetectionAndTracking DPC
  - 2D/3D Object tracking using SDK 3.3 Out of Box detection chain
  - Used in the following demos
    - Long Range People detection
    - Traffic Monitoring
    - Area Scanner
    - Automated Doors and Gates
- TrackerProcCapon DPU and Capon3D DPC
  - 2D/3D Object Tracking using Capon beamforming detection chain
  - Used in the following demos
    - 3D People Counting Demo – Side Mount
    - 3D People Counting Demo – Overhead Mount
    - Sense and Direct HVAC Control Demo
- StaticDetProc DPU and StaticObjeDet DPC
  - 2D/3D Object tracking using SDK 3.3 Out of Box detection chain with added Static detection capability
  - Used in the following demos
    - Area Scanner
    - Automated Doors and Gates
- Available in Industrial Toolbox 4.x download under **C:\ti\mmwave_industrial_toolbox_4_x_x\labs\common**



Area Scanner and Automated Doors

- Custom processing chain developed for Area Scanner and Automated Doors Demos.
- Based on xWR68xx OOB Range-Doppler Detection Chain with addition of 2D AoA using DSP
- Adds Object Tracking and Static Detection Capabilities



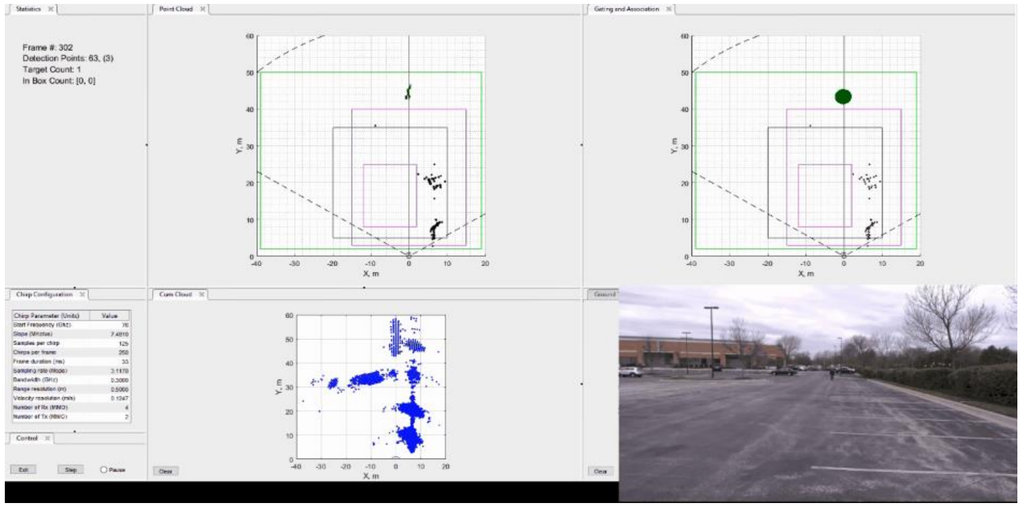


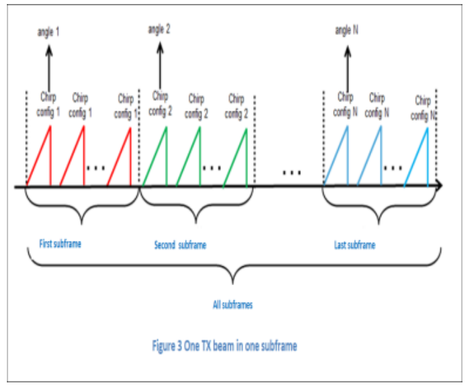
Demo: Long Range Outdoor People Detection and Tracking

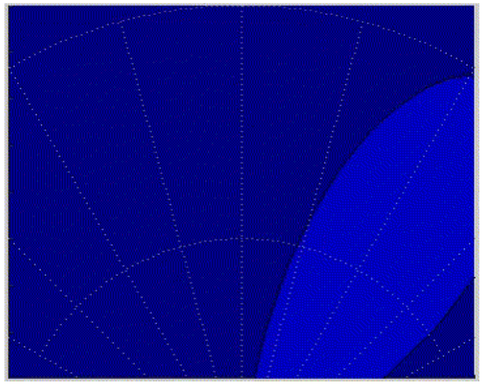
100m People Detection and Tracking

- **Features**
  - SDK 3.3 Range Doppler Detection Chain with Object tracking on R4F
  - Tracker DPU developed on top of SDK 3.x
  - Runs on IWR6843ISK ES2.0 and IWR1843BOOST
  - Supports 2D and 3D tracking
  - People tracking tested upto 100m with IWR6843ISK ES2.0 (3TX SIMO)
  - Re-used for Traffic Monitoring Demo on IWR1843/6843
  - Supports ISK, ODS and AOP antennas (for Indoor applications such as Area Scanner with Static Detection)
    - DSP based AoA DPU modified to add 2D DoA for ODS/AOP
  - Built on SDK 3.x OOB Demo
    - Advanced features included for free e.g. Run time CFAR tuning, FoV filtering, ADC data streaming over LVDS.

Overview

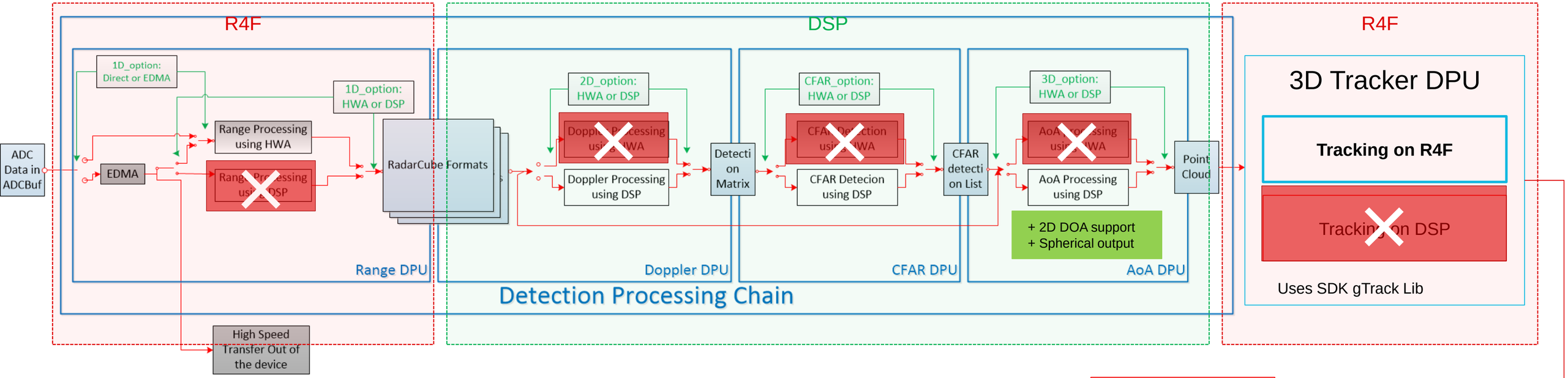






Sub frame based TX Beam Steering

3D Long Range Tracker Chain



Denotes new or modified components

Denotes Unused Datapath

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