What’s new since 17.3.x
(Changes from BISON to KUDU, including OFDMA iovars)

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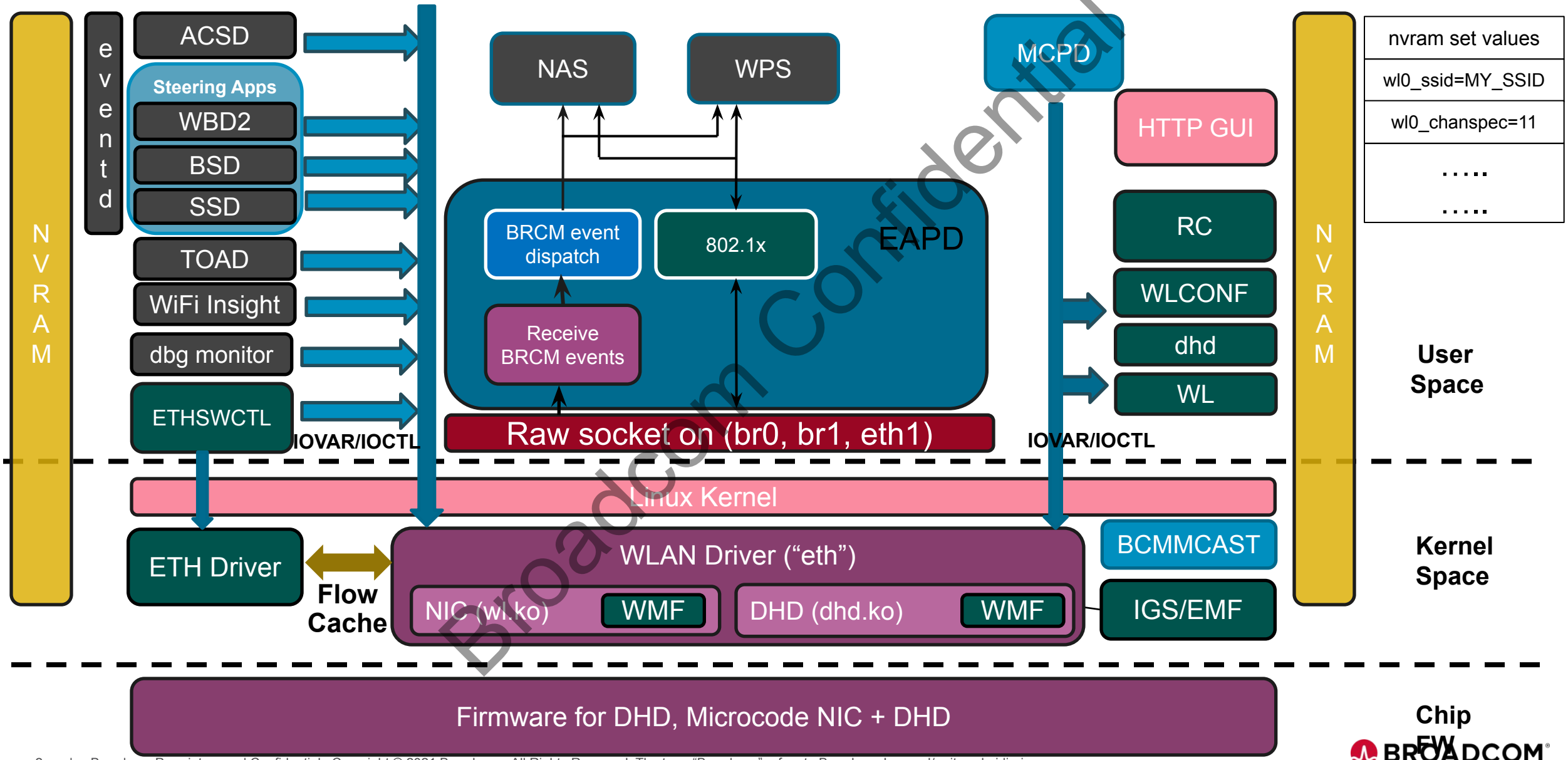
Pre-KUDU WLAN Access Point System Architecture (NAS based)



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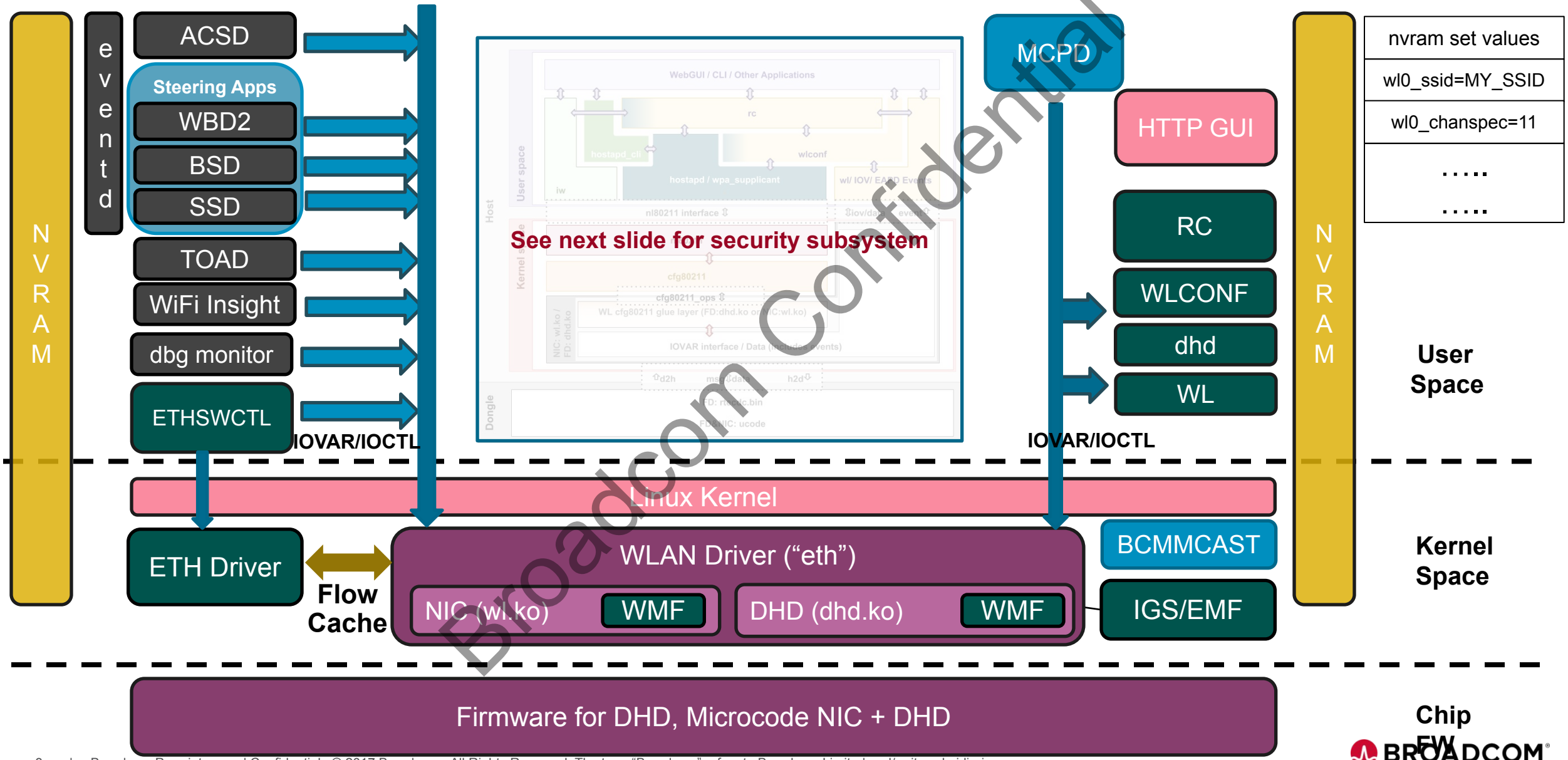
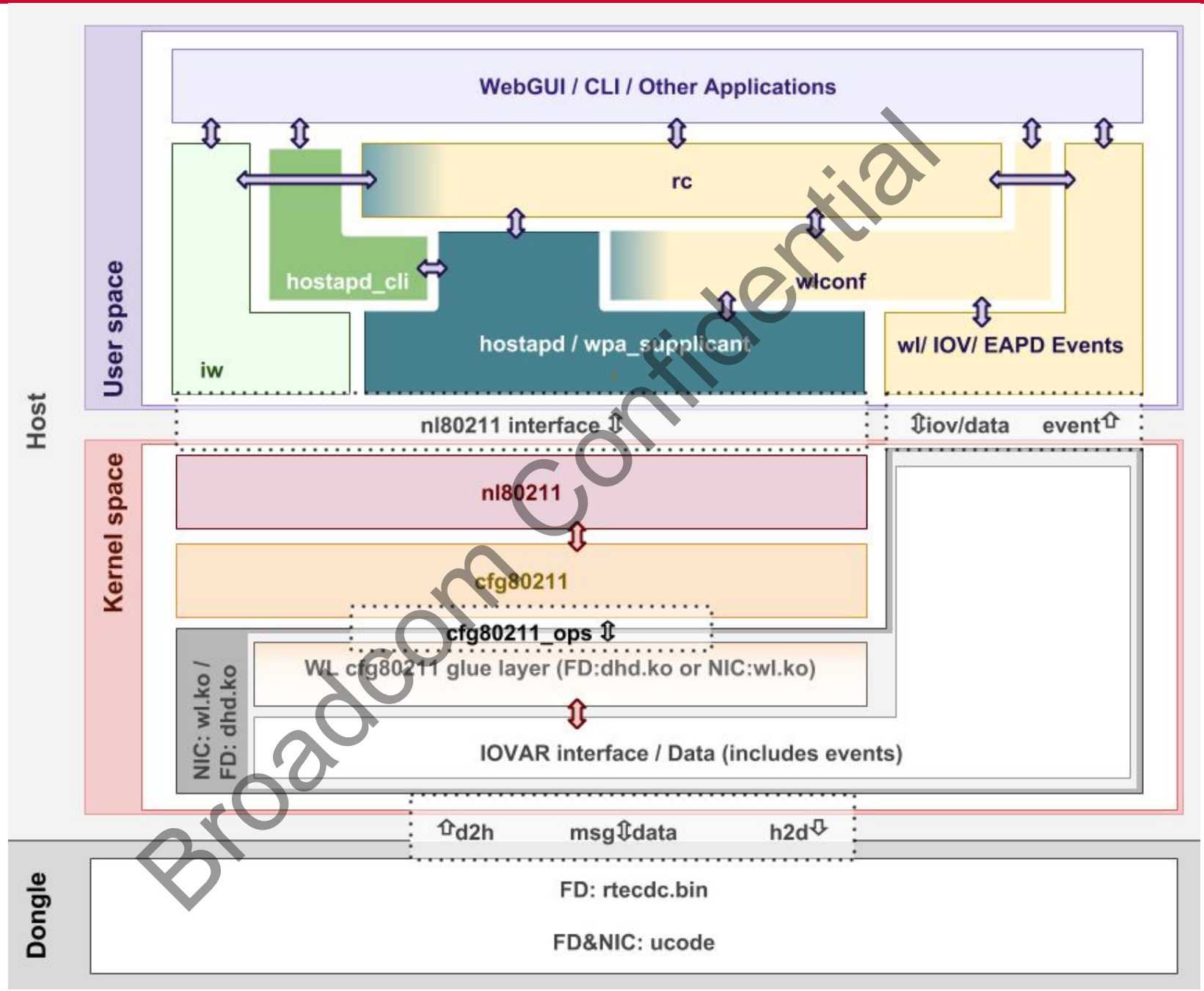
KUDU Wireless Access Point - WLAN Sub-System Architecture



KUDU Security Subsystem Blocks and Interactions

(hostapd based)



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Key application space changes in 18.x (KUDU)

- ACSDv2
  - Introducing a new Auto Channel Selection daemon
  - Based on customer feedback, consolidated SCS and FCS modes
    - SCS switches too slow
    - FCS switches too fast
    - ACSDv2 will be “just right”
  - **Included in 18.1 for retail customers, enabled in 18.2-ea2 (17.10.60) for operator customers**

- Linux open source APIs and applications
  - Official support for cfg80211, nl80211, hostapd, wpa_supplicant
  - **To be released for production in 18.2** (Mar-2019)
  - Requested by partners for middleware compatibility with other vendors
  - Is our upgrade path to WPA3
  - **Available since 18.2-ea2 (17.10.60) but disabled by default, enabled by default in 18.2-ea4 (17.10.77.3)**

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Key driver changes in 18.x (KUDU)

- Enhanced Datapath Scheduler
  - Preserve legacy SU scheduling capabilities: ATF, IAS, NAR
  - Preserve 11ac MU-MIMO grouping and release
  - Introduce 11ax OFDMA grouping and release
  - Consolidated, single scheduler

WL commands / driver IOVARs (for 11ax)

- No redesign of driver API for 11ax
- Existing IOVARs all carried forward
- A few updates or new IOVARs
  - wl he <command> (only in 18.1 and later releases)
  - wl twt <command> (only in 18.2.1 and later releases)
  - wl sr_config <command> (only in 19.1 and later releases)
  - wl 2g_rate, wl 5g_rate, now include HE rates
  - wl rateset, now includes HE rates
  - wl txbf_bfe_cap, wl txbf_bfr_cap (meaning of existing parameters changed)
  - wl phy_rssi_ant (meaning of existing parameters changed)

wl he [command] [cmd options]

```
# wl he -h
he      HE (802.11ax) protocol control commands

        Usage: wl he [command] [cmd options]

Available commands and command options:
        wl he enab [0|1] - query or enable/disable HE feature
        wl he features [<features mask>] - query or enable/disable HE sub-features
        wl he bsscolor [<color> [-w(ait) <beacon count>]] - set or get color value
                set color 0 to disable, wait is used by Color Change IE, use 0 for immediate update
        wl he muedca [<aci> <aifsn> <ecw min> <ecw max> <timer>] -
                query or set HE MU EDCA parameters
        wl he ppet [0|8|16|auto] - override ppet settings for all. (test only)
        wl he htc <code> - transmit HTC code. (test only)
        wl he omi [-a address] [<options>]
        wl he sr [-d] [<options>]
```

- Suggestion is to leave these settings at their default values
  - Mostly intended for testing/debug or specific scenarios

wl he features [<features mask>]

- Get or set HE sub-features
- HE features bitmap.
  - Bit 0: HE SU 5G support
  - Bit 1: HE SU 2G support
  - Bit 2: HE DL OFDMA support
  - Bit 3: HE UL OFDMA support
  - Bit 4: HE DL MU-MIMO support
  - Bit 5: HE UL MU-MIMO support (21.1, 6715 only)
  - Bit 6: HE STA UL MU support (20.1, STA operation)
  - Bit 7: HE Extended Range SU RX support (21.1, 6715 only)
  - Bit 8: HE Extended Range SU TX support (21.1, 6715 only)

- **18.1** release defaults to **"he features 3"**
  - No OFDMA, only 11ax SU
- **18.1.1** release defaults to **"he features 7"**
  - First production support for (DL) OFDMA
- **18.2** release defaults to **"he features 15"**
  - First production support for UL OFDMA
- **18.2.1** release defaults to **"he features 31"** for 43684 and **"he features 15"** for other chips
- **19.1(.x)** release defaults to **"he features 31"** for all chips

wl he omi [-a address] [<options>]

- Allows to send OMI codes to clients or to AP (as STA)
- Intended for testing/debug, should not be needed for normal operation
- Configured OMI settings are applied to the device (for the connection to the remote device) and sent to remote device using a HTC code
  - Note: For sending an OMI code that is applied by receiver but has no effect on transmitter, one should use the wl he htc command instead.
-

```
wl he omi [-a address] [<options>]
        <options>:
                -t <tx nsts> (1..8)
                -r <rx nss> (1..8)
                -b <20|40|80|160>
                -e <er su disable> (0|1)
                -s <dl mu-mimo resounding recommendation> (0|1)
                -u <ul mu disable> (0|1)
                -d <ul mu data disable> (0|1)
```


wl he sr [-d] [<options>]

- Used for configuration of Spatial Reuse Parameter Set IE
- Default is ‘disabled’ which means that the IE is not included in beacons, probe responses and (re-association) responses
- Note that configuration and inclusion of this IE is independent of SR operation by AP (as configured by wl sr_config, see one of next slides)
- Options:

```
wl he sr [-d] [<options>]
        -d - disable IE, rest of cmdline (options) is ignored when set
        <options>:
                -p <0|1> - PSR disallowed
                -o <0|1> - Non-SRG OBSS PD SR Disallowed
                -n <0|1> [<data>] - Non-SRG Offset Present, 1 byte data (hex or dec) if set to 1
                -s <0|1> [<data>] - SRG Information Present, 18 bytes data if set to 1
                -h <0|1> - HESIGA_Spatial_reuse_value15_allowed
```


wl sr_config [command] [cmd options]

```
wl sr_config options [0/1/2]: 0: Disable SR, 1: Enable on HE PPDU  SR, 2: Enable SR on HE and VHT PPDU
wl sr_config nsrg_pdmin [value]: get/set NON SRG OBSS PDMIN value
wl sr_config nsrg_pdmax [value]: get/set NON SRG OBSS PDMAX value
wl sr_config srg_pdmin [value]: get/set SRG OBSS PDMIN value
wl sr_config srg_pdmax [value]: get/set SRG OBSS PDMAX value
wl sr_config txpwrref [value]: get/set tx power reference value
wl sr_config nsrg_txpwrref0 [value]: get/set NON SRG tx power reference0 value
wl sr_config srg_txpwrref0 [value]: get/set NON SRG tx power reference0 value
wl sr_config srg_obsscolorbmp0 [value]: get/set SRG OBSS Color Bitmap0 value
wl sr_config srg_obsscolorbmp1 [value]: get/set SRG OBSS Color Bitmap1 value
wl sr_config srg_obsscolorbmp2 [value]: get/set SRG OBSS Color Bitmap2 value
wl sr_config srg_obsscolorbmp3 [value]: get/set SRG OBSS Color Bitmap3 value
wl sr_config sr_cnts: get SR opportunity and tx counters value (Disable SR will reset the cnts)
```


Notes for BSS Color and Spatial Reuse

- Our driver will pick a random BSS color upon bootup unless someone uses "wl he bsscolor" to set to a specific color
- There are AP side and STA side Spatial Reuse (SR) operations. They are disabled by default
  - The AP side SR operations can be enabled/disabled and configured by using the "wl sr_config" command. There is nothing in the beacon to indicate that. One can enable the AP side SR operation in 19.1.1 without any additional patches.
  - The STA side SR operation will require AP to send "Spatial Reuse Parameter Set" IE in the beacon. Without that, the STAs will not do SR handling. With 19.1.1 release, additional patches are needed to send the "Spatial Reuse Parameter Set" IE in the beacon and those patches will add a new command "wl he sr" for enabling/disabling and configuring this IE.
- In order for SR to be beneficial, one will need to have a centralized planning and coordination across all the APs/repeaters involved in an environment/SR network. Broadcom does not have an application for such centralized planning and coordination. Someone else would need to develop such centralized application and then use Broadcom APIs to configure each AP/repeater properly.

wl twt [command] [cmd options]

```
# wl twt -h
twt     TWT protocol control commands

        Usage: wl twt [command] [cmd options]

Available commands and command options:
        wl twt enab [0|1] - query or enable/disable TWT feature
        wl twt setup [<flow flags>] [<options>] - setup target wake time (TWT)
                <flow flags>:
                        -b - Broadcast TWT
                        -i - Implicit TWT
                        -u - Unannounced
                        -t - Trigger
                        -r - Protection
                <options>:
                        -a <peer MAC address>
                        -c <request|suggest|demand> - default <request>
                        -d <wake duration> - 256us unit
                        -p (wake interval) <mantissa> <exponent>
                        -I <(broadcast/individual) id>
        wl twt teardown [<flow flags>] [<options>] <id> - teardown flow
                <flow flags>:
                        -b - Broadcast TWT
                <options>:
                        -a <peer MAC address>
```


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wl twt [command] [cmd options] (Continued)

```
wl twt info [<flow flags>] [<options>] <flow id> - request information
        <flow flags>:
                -r - response request
        <options>:
                -a <peer MAC address>
                -w <target wake time>
wl twt list [<options>] - list all twt info (bcast & indvidual)
        <options>:
                -a <peer MAC address>
```

- Some commands are for client/STA support and/or development/debug:
  - wl twt setup & wl twt info - not recommended to be used.
  - wl twt setup will become available for AP to setup broadcast TWT in later driver versions
  - wl dump twt can be used to get complete list of individual TWT connections (debug builds only)
- TWT is only supported in AP mode.
- Next slides describe the TWT commands that are available in AP mode.

wl twt [enab] [0|1]

- wl twt [enab] [0|1]
  - Set or Get to query or set the TWT state.
  - By default TWT is enabled since 18.2.1 GA release
  - Setting the TWT state is only possible when interface is down.

wl twt teardown [<-a MAC address>] <flow id>

- wl twt teardown [<-a MAC address>] <flow id>
  - On AP MAC address needs to be provided.
  - Use wl twt list to determine possible values for flow id

wl twt list [<-a MAC address>]

- wl twt list [<-a MAC address>]
  - On AP MAC address needs to be provided.
  - use wl dump twt to get list of all schedules (not available in production image).

```
# wl twt list -a 00:90:4C:89:0B:95

        1 Individual TWT schedules available:

ID    Interval (usec)   Duration (usec)   Channel   Unannounced   Trigger   Protection
 0)     163840            16384            0x00         YES         NO          NO
```


wl 5g_rate, wl 2g_rate

- Addition of -e for HE rates and -i for HE Guard Interval

```
# wl 5g_rate -h
wl_rate: missing value parameter after "-h"
5g_rate Force a fixed rate for data frames in the 5G band:

        Either "auto", or a simple OFDM rate value:
        6 9 12 18 24 36 48 54

        Or options to specify legacy OFDM, HT, or VHT rate:
        -r R, --rate=R          : legacy OFDM rate
        -h M, --ht=M            : HT MCS index [0-23]
        -v M[xS], --vht=M[xS]   : VHT MCS index M [0-9],
                                : and optionally Nss S [1-8], eg. 5x2 is MCS=5, Nss=2
        -c cM[sS]               : VHT (c notation) MCS index M [0-9],
                                : and optionally Nss S [1-8], eg. c5s2 is MCS=5, Nss=2
        -e M[xS], --he=M[xS]    : HE rate M [0-11],
        -s S, --ss=S            : VHT Nss [1-8], number of spatial streams, default 1.
                                : Only used with -v/--vht when MxS format is not used
        -x T, --exp=T           : Tx Expansion, number of tx chains (NTx) beyond the minimum
                                : required for the space-time-streams, exp = NTx - Nsts
        --stbc                  : Use STBC expansion, otherwise no STBC
        -l, --ldpc              : Use LDPC encoding, otherwise no LDPC
        -g, --sgi               : Guard interval. Different values for HT/VHT
                                : Use Short Guard Interval otherwise standard GI
        -i, --hegi              : Guard interval. Different values for HE
                                : For HE cp_ltf combination allowed values (0,1,2,3)
        -b, --bandwidth         : transmit bandwidth MHz; 2.5, 5, 10, 20, 40, 80, 160
```


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wl 5g_rate -e M[xS]

- wl 5g_rate -e M[xS]
  - Set the transmit rate
  - Not advised other than lab testing
  - Example:

```
# wl 5g_rate
auto
# wl 5g_rate -e 9x2
wl_rate: Warning LDPC is required for HE > 20MHz
# wl 5g_rate -l -e 9x2
# wl 5g_rate
he mcs 9 Nss 2 Tx Exp 0 BW auto ldpc 2xLTF GI 0.8us
```

wl 5g_rate -i l

- wl_5g_rate -i l
  - Set the HE Guard interval
  - For HE cp_ltf combination allowed values
    - 0 - 1xLTF GI 0.8us **(Not supported)**
    - 1 - 2xLTF GI 0.8us
    - 2 - 2xLTF GI 1.6us
    - 3 - 4xLTF GI 3.2us
  - Example:

```
# wl 5g_rate
he mcs 9 Nss 2 Tx Exp 0 BW auto ldpc 2xLTF GI 0.8us
# wl 5g_rate -l -e 9x2 -i 3
# wl 5g_rate
he mcs 9 Nss 2 Tx Exp 0 BW auto ldpc 4xLTF GI 3.2us
```


wl rateset

- Support for configuring HE rates for 1..4 stream operation

```
# wl rateset -h
unable to convert the rate parameter "-h"
rateset Returns or sets the supported and basic rateset, (b) indicates basic
        With no args, returns the rateset. Args are
        rateset "default" | "all" | <arbitrary rateset> [-m|-v|-e <list of mcs masks>]
                default - driver defaults
                all - all rates are basic rates
                arbitrary rateset - list of rates
        List of rates are in Mbps and each rate is optionally followed
        by "(b)" or "b" for a Basic rate. Example: 1(b) 2b 5.5 11
        At least one rate must be Basic for a legal rateset.

        -m  sets HT rates (bitmasks, 00-ff). Least significant bit is MCS0.
            example: 'rateset -m 0x3f 0x01' limits rates to MCS0-MCS5 and MCS8

        -v  sets VHT MCS values for each supported count of spatial streams.
            example: 'rateset -v 3ff 1ff ff fff' limits vht rates to MCS 0-9 for 1 stream,
              MCS 0-8 for 2 streams, MCS 0-7 for 3 streams, and MCS 0-11 for 4 streams.

        -e  sets HE MCS values for each supported count of spatial streams.
            example: 'rateset -e 3ff 3ff ff fff' limits HE rates to MCS 0-9 for 1 stream,
              MCS 0-9 for 2 streams, MCS 0-7 for 3 streams, and MCS 0-11 for 4 streams.
```


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wl rateset example

- Probably don't need to change the rateset in practice!
- Example:

```
# wl down
# wl rateset -e ff ff 3ff fff
# wl rateset
[ 1(b) 2(b) 5.5(b) 6 9 11(b) 12 18 24 36 48 54 ]
MCS SET : [ 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 ]
VHT SET : 0x1 1x1 2x1 3x1 4x1 5x1 6x1 7x1 8x1 9x1 10x1 11x1
        : 0x2 1x2 2x2 3x2 4x2 5x2 6x2 7x2 8x2 9x2 10x2 11x2
        : 0x3 1x3 2x3 3x3 4x3 5x3 6x3 7x3 8x3 9x3 10x3 11x3
        : 0x4 1x4 2x4 3x4 4x4 5x4 6x4 7x4 8x4 9x4 10x4 11x4
HE SET  : 0x1 1x1 2x1 3x1 4x1 5x1 6x1 7x1
        : 0x2 1x2 2x2 3x2 4x2 5x2 6x2 7x2
        : 0x3 1x3 2x3 3x3 4x3 5x3 6x3 7x3 8x3 9x3
        : 0x4 1x4 2x4 3x4 4x4 5x4 6x4 7x4 8x4 9x4 10x4 11x4
```

Adjust rateset for 1, 2, 3, and 4 stream operation.

HE rateset is now operating with the new values.

- Not a full bitmask, only ff, 3ff, fff are valid options

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wl txbf_bfe_cap [options]

- Enable/disable beamformee capability
  - Used to be value, 0, 1, 2
  - Now a bitmask:
    - **#define TXBF_SU_BFE_CAP 0x01**
    - **#define TXBF_MU_BFE_CAP 0x02**
    - **#define TXBF_HE_SU_BFE_CAP 0x04**
    - **#define TXBF_HE_MU_BFE_CAP 0x08**
    - **#define TXBF_HE_CQI_BFE_CAP 0x10**
  - In old code a value of 2 requires a new bitmask of 0x3.

Note that the values have changed meaning in KUDU!

wl txbf_bfr_cap [options]

- Enable/disable beamformer capability
  - Used to be value, 0, 1, 2
  - Now a bitmask:
    - **#define TXBF_SU_BFR_CAP 0x01**
    - **#define TXBF_MU_BFR_CAP 0x02**
    - **#define TXBF_HE_SU_BFR_CAP 0x04**
    - **#define TXBF_HE_MU_BFR_CAP 0x08**
    - **#define TXBF_HE_CQI_BFR_CAP 0x10**
  - In old code a value of 2 requires a new bitmask of 0x3.
  - “he features 7” is a necessary condition to turn on HE_MU_BFR_CAP
  - Setting the value 15 means vht su + vht mu + he su + he mu bfr

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wl phy_rssi_ant <macaddr>

- In AP mode, the wl phy_rssi_ant command now has a mandatory parameter, the MAC address of the (associated) station:
  - Example:

```
# wl phy_rssi_ant
wl: Unsupported
# wl assoclist
assoclist 00:90:4C:89:04:F5
# wl phy_rssi_ant 00:90:4C:89:04:F5
rssi[0] -73  rssi[1] -74  rssi[2] -74  rssi[3] -74
```

Note: first time command is used for a specific STA, it may not return valid output (in case insufficient RSSI information has been gathered)

6GHz support in 20.x (KUDU)

- 6GHz support provided on 43684c0, 6710, 675x, etc (but not on 43684b1 and earlier)
- 6GHz support is added to all existing band/channel related commands, e.g.
  - wl band 6g (the band command now also accepts wl band 2g or wl band 5g in addition to legacy wl band b or wl band 2g)
  - wl chanspec 6g5/160 (refers to primary channel 5 on 6g band with, 160MHz BW, command now also accepts wl chanspec 2g5 in addition to wl chanspec 5)
  - New command to fix rate on 6g with similar parameters as wl 2g_rate/wl 5g_rate:

```
# wl 6g_rate -h
wl_rate: missing value parameter after "-h"
6g_rate Force a fixed rate for data frames in the 6G band:

        Either "auto", or options to specify HE rate:
        -e M[xS], --he=M[xS]   : HE rate M [0-11],
        -s S, --ss=S           : HE Nss [1-8], number of spatial streams, default 1.
                               : Only used with -e/--he when MxS format is not used
        -x T, --exp=T          : Tx Expansion, number of tx chains (NTx) beyond the minimum
                               : required for the space-time-streams, exp = NTx - Nsts
        --stbc                 : Use STBC expansion, otherwise no STBC
        -l, --ldpc             : Use LDPC encoding, otherwise no LDPC
        -i, --hegi             : Guard interval. Different values for HE
                               : For HE cp_ltf combination allowed values (0,1,2,3)
        -b, --bandwidth        : transmit bandwidth MHz; 20, 40, 80, 160
```


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wl nbr_discovery_cap [bitmap]

- wl nbr_discovery_cap [0|32|64|...]
  - Set or Get to query neighbor discovery capabilities
  - 0: Disabled/none
  - 32: Unsolicited Probe Response (UPR) - Default on 6GHz
  - 64: FILS Discovery Frames (FD)

List of bitmap positions:

```
0: WLC_6G_CAP_RNR_IE
1: WLC_6G_CAP_PRB_RSP_CANCEL
2: WLC_6G_CAP_COLOCATED_RADIO
3: WLC_6G_CAP_IN_BAND_DISCOVERY
4: WLC_6G_CAP_OOB_DISCOVERY
5: WLC_6G_CAP_20TU_BCAST_PRB_RSP
6: WLC_6G_CAP_20TU_FILS_DISCOVERY
7: WLC_6G_CAP_NO_WILDCARD_PRBREQ
```

(Note: Can not use both UPR and FD simultaneously)

wl scan [args]

- wl scan [args]
  - Default to a passive full scan across all channels
  - Supports all arguments as for other bands. See wl -h scan for details.
    - eg. Optional arg: SSIDs, list of [up to 10] SSIDs to scan (comma or space separated).

```
-s S, --ssid= SSID's   An active full scan across all channels for given SSID's
—
```

  - New options specific to 6GHz operation

```
-P  1       PSC Scanning.  Prepares PSC channel list and scans PSC channels. Scan will
perform 25 ms passive scanning and active scanning for dwell time of 50 ms on each
channel after receiving FILS Discovery frame.

-R 1       RNR Scanning.  Prepares RNR channel list and scans only RNR channels. Scan
will perform active scanning for dwell time 50 ms on each channel.

-b MAC, --bssid=MAC     particular BSSID MAC address to scan, xx:xx:xx:xx:xx:xx. Scan
will perform active scanning for dwell time 50 ms on each channel.
```


wl fd_prb_rsp_period [TUs]

- wl fd_prb_rsp_period [TUs]
  - Set or Get to query UPR/FD periodicity in TUs
  - Defaults to 20 TUs
    (1TU ~= 1ms)

wl mbssid [0|1]

- wl mbssid [0|1]
  - Set or Get to query if MBSSID is enabled
  - By default MBSSID is enabled on 6GHz interfaces
  - Toggling MBSSID effects only when the interface is brought up

wl block_nonmbssid [0|1]

- wl block_nonmbssid [0|1]
  - Set or Get to query if non-MBSSID capable clients must be blocked
  - 0 by default

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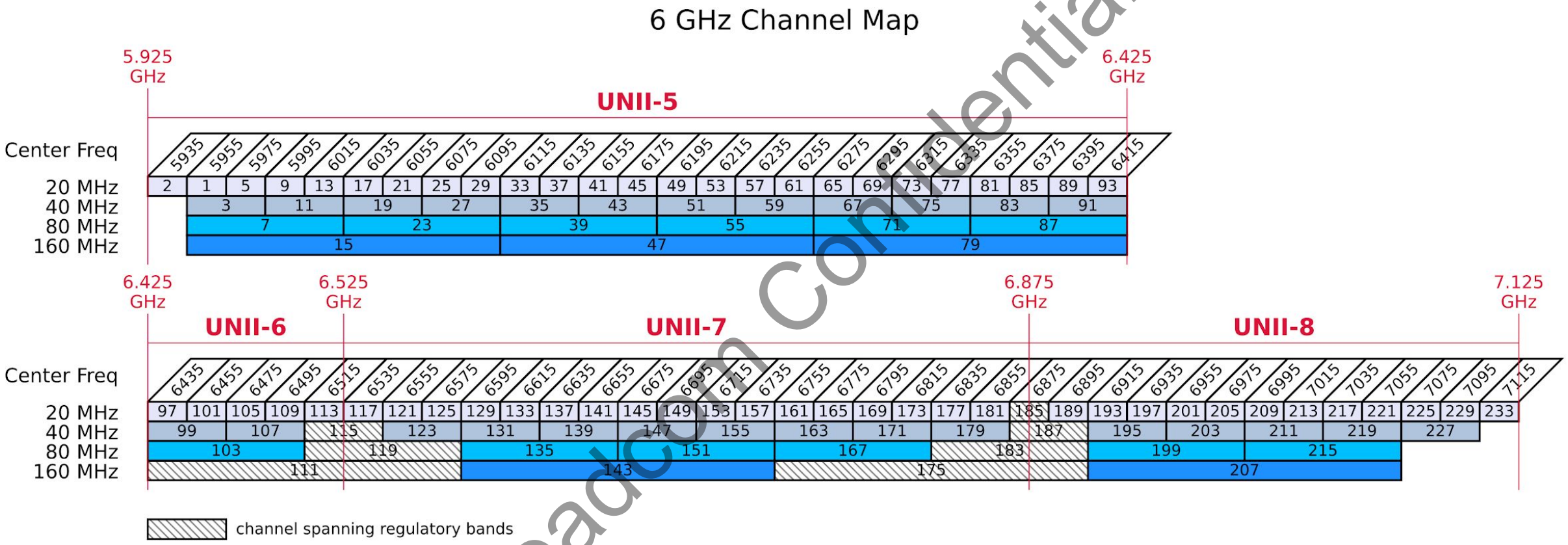
6GHz Channel Map



Note: driver utility uses wl chanspec 6g<primary 20MHz channel>/<channel BW> format

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Thank You