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Graphics and Wireless for STM32 MCUs

STMicroelectronics

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Agenda

1. STM32 Graphics hardware and software solution
2. STM32 Wireless solution
3. “Graphics with Wireless” implementation

STM32 Graphics hardware and software solution

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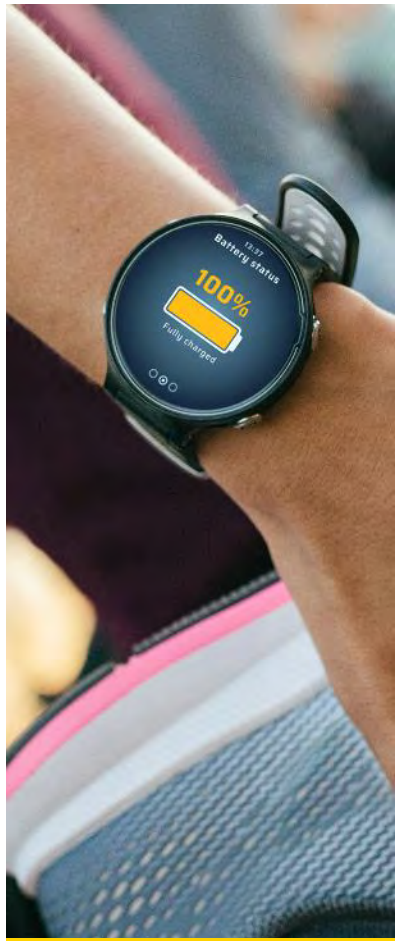
So many applications requiring real-time user interfaces

EV chargers

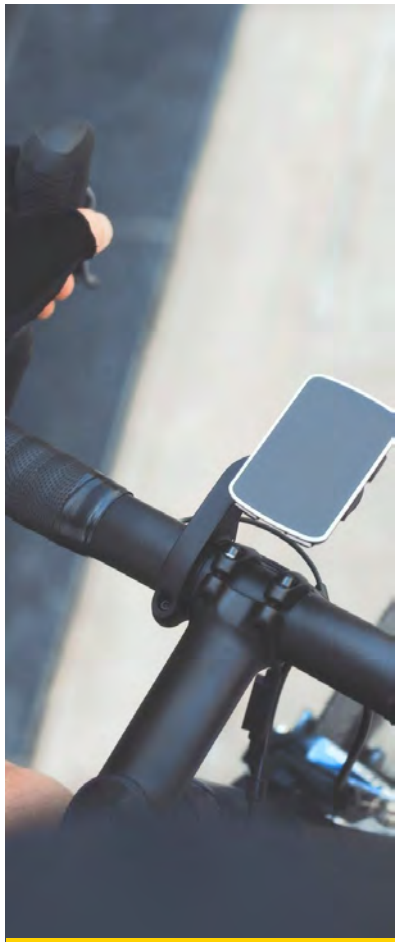
Home appliances



Wearables

Thermostat

Smart homes


e-bikes

And many more…

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STM32 MCU graphics examples of achievable UI performance

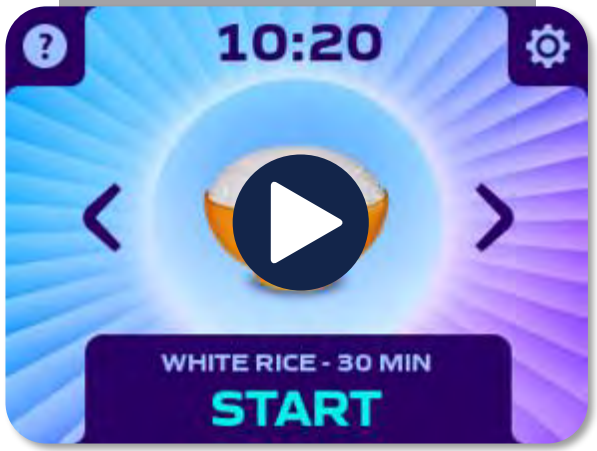
STM32C0

+

TouchGFX

Display resolution **up to 320x240**

Entry level - Internal RAM



High level - Internal RAM

STM32U5

+

TouchGFX

Display resolution **up to 1024x768**

STM32H5

+

TouchGFX

Display resolution **up to 640x480**

Mid level – internal RAM

High level - External RAM

STM32H7

+

TouchGFX

Display resolution **up to 1280x800**

STM32 hardware embedded graphics HW acceleration

Graphics HW acceleration

Offloads the CPU from graphics tasks
Lower memory consumption
Higher GUI performance – smooth and richer graphics effects

➔ Chrom-ART™ Accelerator

- Alpha blending
- 2D Copy

➔ Neochrom GPU

- Scaling, Rotation
- Perspective correction

➔ NeochromVG GPU

- Scaling, Rotation
- Vector acceleration

➔ JPEG Hardware Accelerator

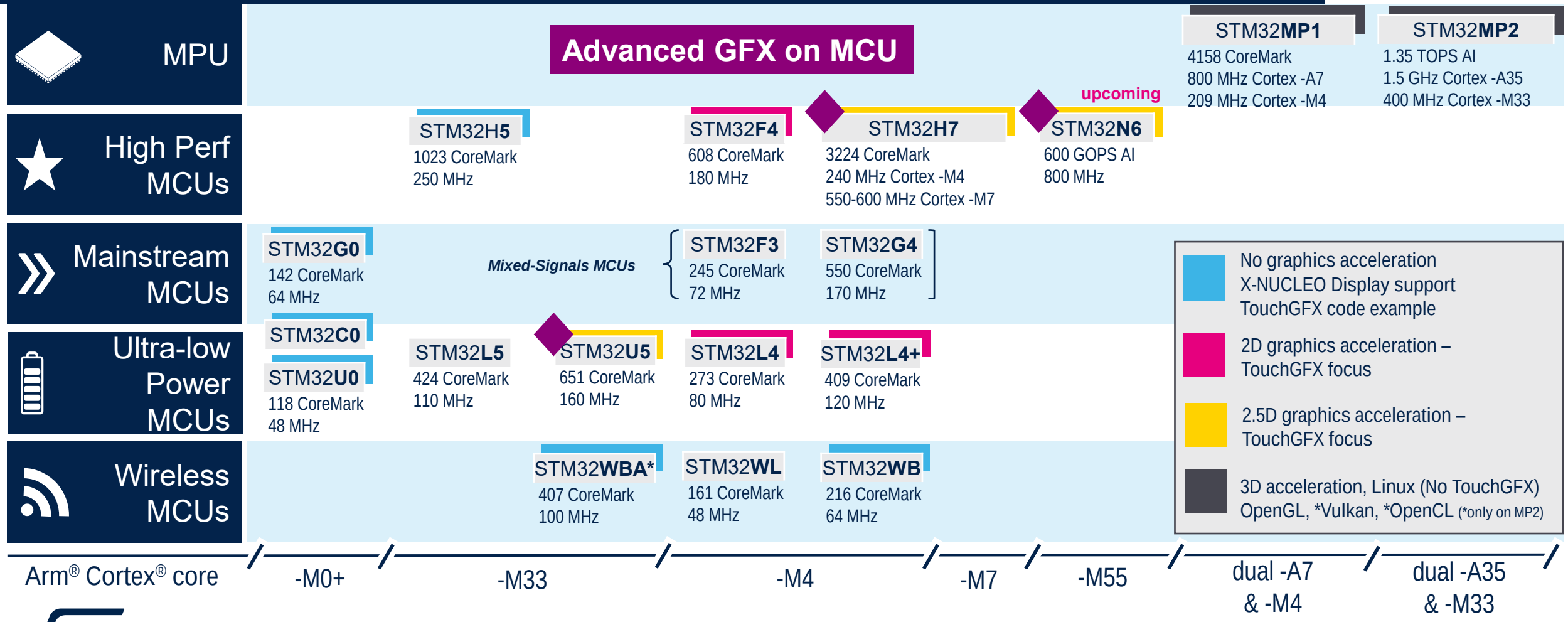
- JPEG compression
- JPEG decompression

Rotation / Perspective / Scaling / Alpha blending

Rotation / Alpha blending / Vector rendering

STM32 Graphics portfolio - Overview

Large choice of STM32 with entry Graphics and Advanced Graphics



*For graphics, WBA is recommended to be used as a coprocessor due to its single-core configuration.

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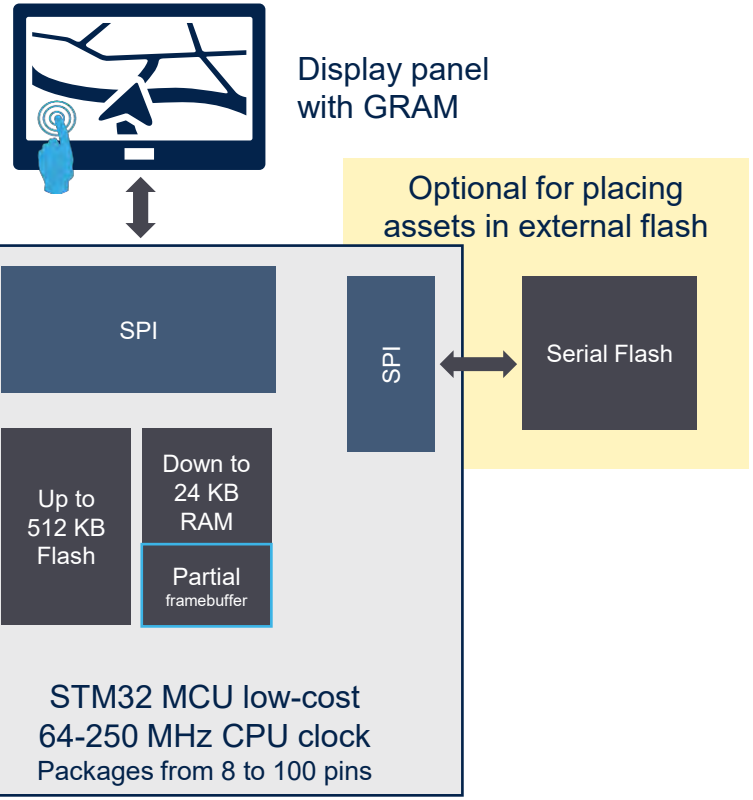
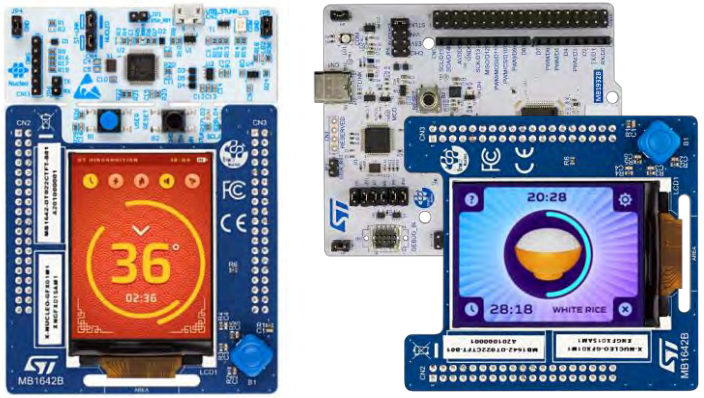
Entry-level graphics on ultra-low-cost STM32G07x/U07x/C07x/H50x

Displays up to 3.5” Up to 320x240



- **NUCLEO board + X-NUCLEO-GFX01M2**
  - 2.2” SPI QVGA 320x240 display
- **TouchGFX Designer**
  - Board specific demos in full source
  - TouchGFX Board setup
  - Note:
    TouchGFX GUI footprint starting from 50kB flash and 16kB RAM (including partial frame buffer)



No external RAM due to partial framebuffer

Advanced Graphics on ultra-low-power MCU STM32U5F9/G9

Displays up to 7” - Approx. 800x480

- **STM32U5G9-DK1**
  - 2.5”, 480x480 display, MIPI-DSI
  - Preloaded TouchGFX demo
- **STM32U5G9-DK2**
  - 4” WVGA, 800x480 LTDC display
  - Preloaded TouchGFX demo

Display panel

External memory (optional)

RGB + MIPI-DSI interface TFT-LCD display controller

Chrom-ART NeoChromVG GPU MJPEG Codec Chrom-GRC

4 MB Flash

3.0 MB RAM

FB 1

FB 2

STM32U5F9
160 MHz, Cortex M33

Octo-SPI

Hexadeca-SPI

SDIO

Flash

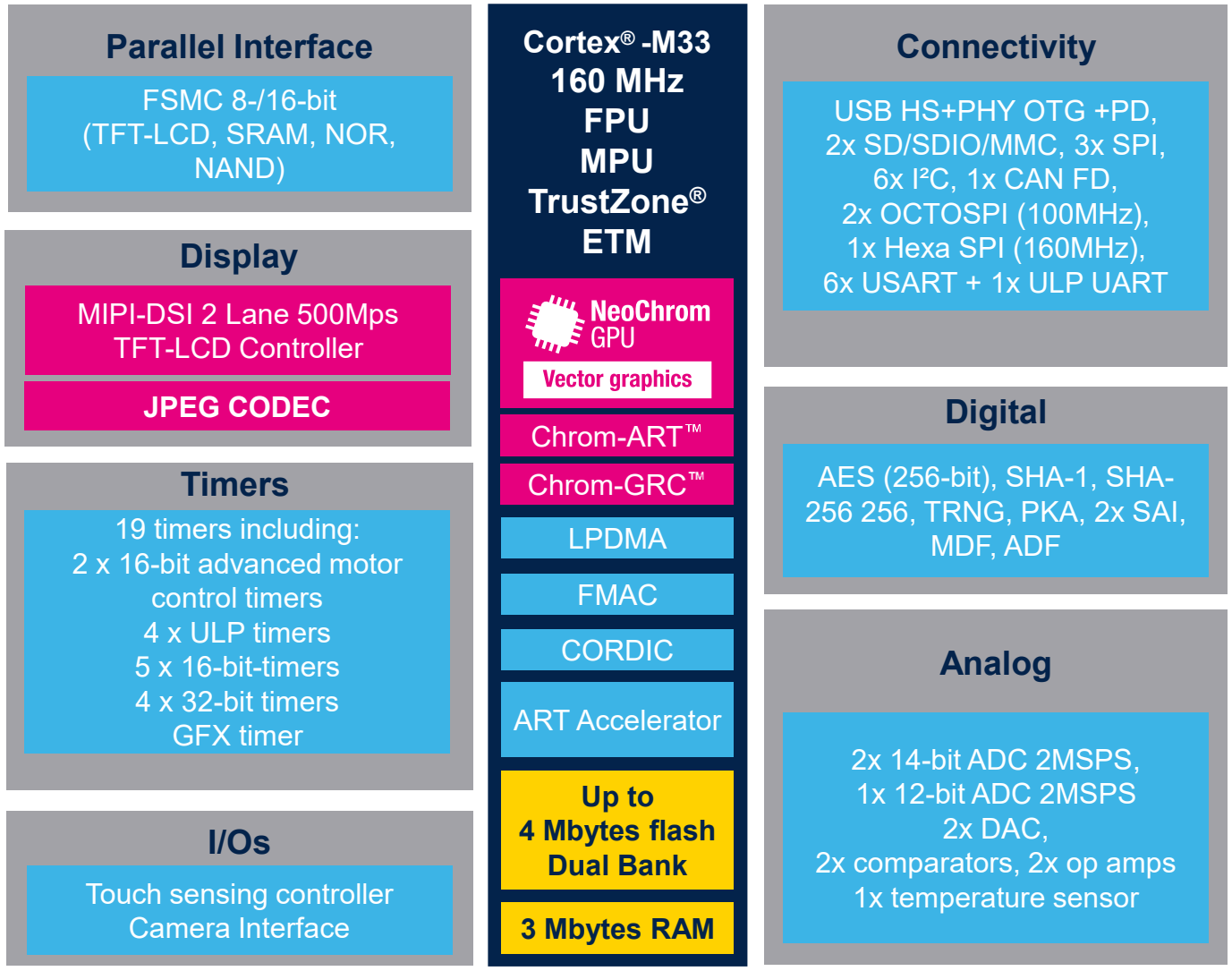
Option if assets in external flash

PSRAM

eMMC

Option if assets in eMMC and cached in PSRAM

STM32U5F9/G9 block diagram



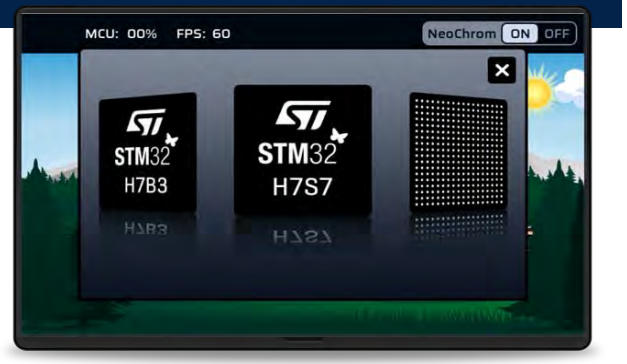
Numerous integrated peripherals

Advanced features for graphics

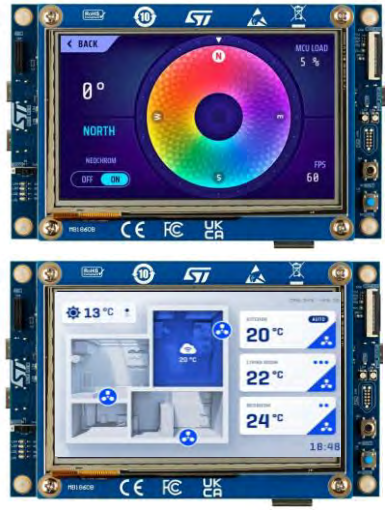
Large embedded memory

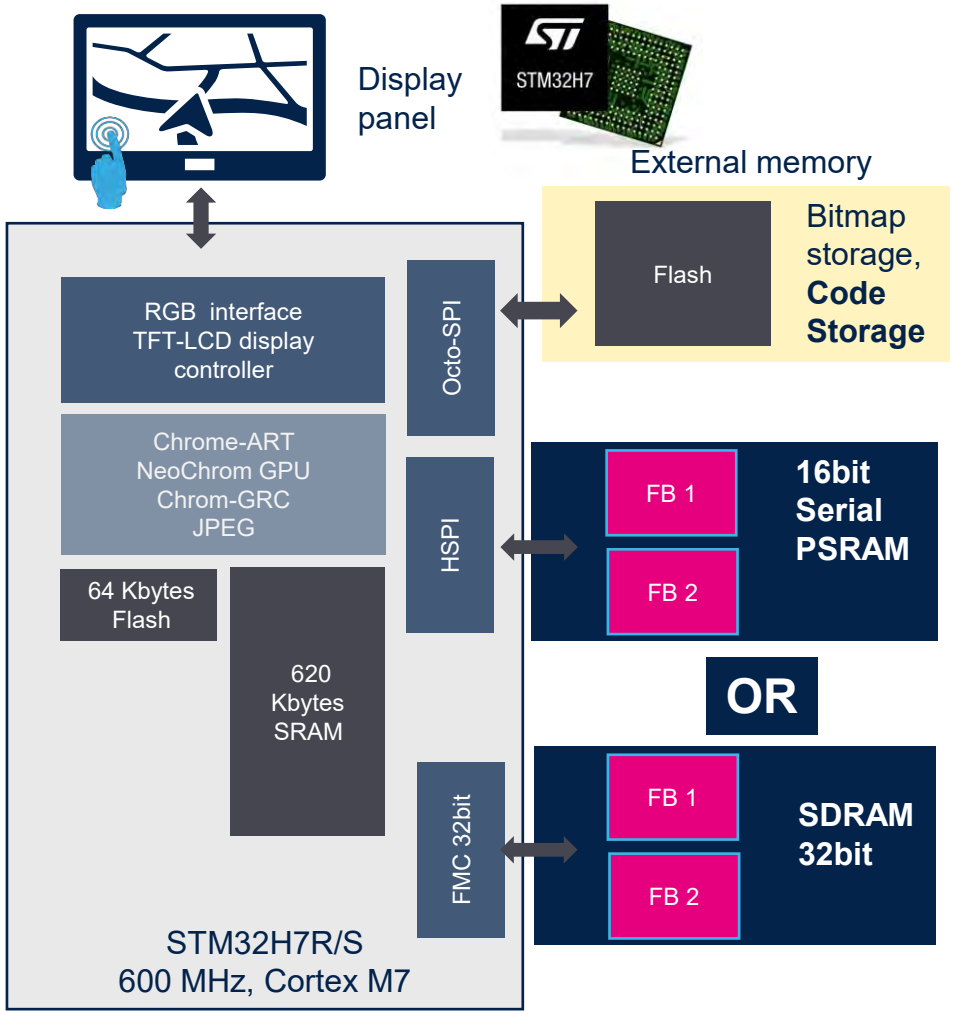
Advanced graphics with external RAM STM32H7R/S

Displays up to 10.1” - Approx. 800x480 / 1280x800

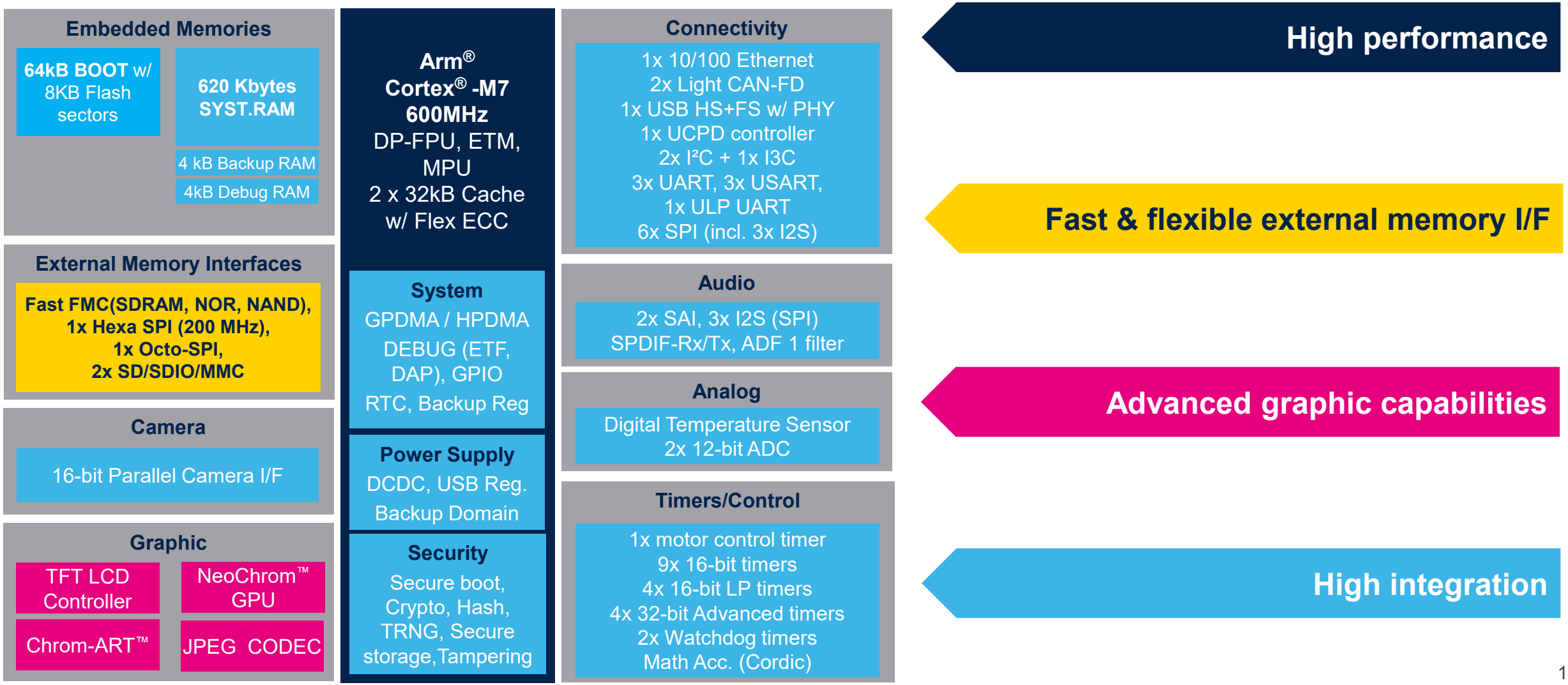


- **STM32H7S7-DK**
  - 4,3” WVGA, 800x480 display
  - OctoSPI Flash + HSPI PSRAM
  - Preloaded TouchGFX demo
- **TouchGFX Designer**
  - Demo in full source
  - TouchGFX Board setup

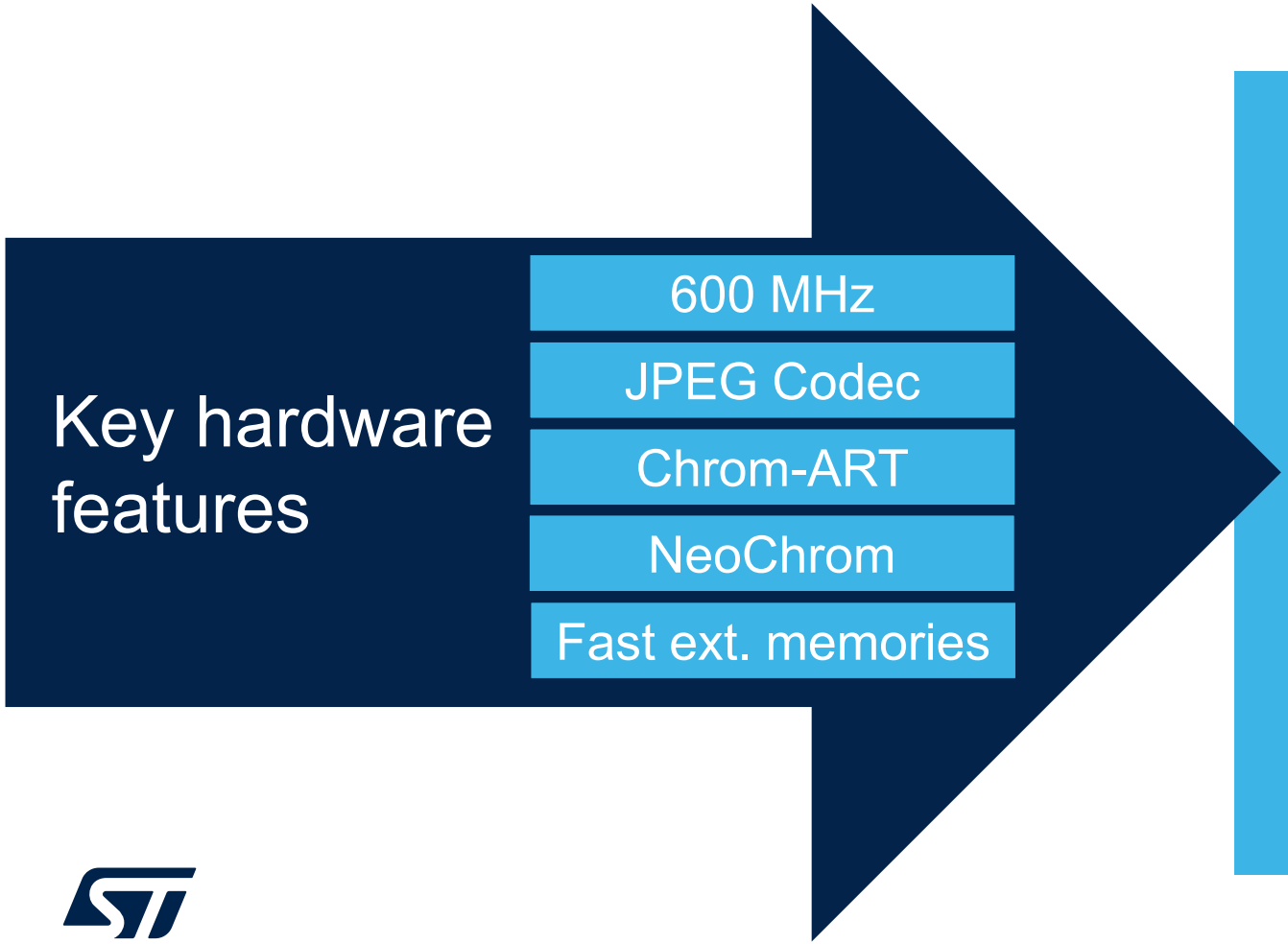




STM32H7RS Block diagram



Continuing the STM32H7 High performance GUI



Video playback

Scaling

60FPS

Low MCU Load

Alpha Blending

Rotation

Texture mapping

And much more

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STM32H7 detailed graphic features

	Features	STM32H7A3/7B0	STM32H723/725	STM32H745/747	STM32H743/750	STM32H7R/S
CPU	**Clock Frequency**	280 MHz	550 MHz	480 MHz	480 MHz	600 MHz
Hardware acceleration	**Chrom-ART Accelerator™** Hardware acceleration for graphical operations	●	●	●	●	●
	Chrom-GRC™ Minimizing memory usage for round displays	●	-	-	-	●
	JPEG CODEC Optimized video playback	●	-	●	●	●
	NeoChrom GPU™ High-end GPU for MCUs (rotation, scaling)	-	-	-	-	●
Memory interfaces	**Quad-SPI** Connecting QSPI Flash	●	●	●	●	●
	Octo-SPI Connecting Octo SPI flash or Octal RAM	●	●	-	-	● (+HSPI)
	FMC Connecting parallel flash, SDRAM, PSRAM	●	●	●	●	● (up to 32 bits)
	SDMMC Connecting eMMC, MMC,	●	●	●	●	●
Display interfaces	**LCD-TFT display controller**	●	●	●	●	●
	MIPI-DSI	-	-	●	-	-
	Parallel 8080/6800	●	●	●	●	●
Embedded memory	**Embedded SRAM** **for framebuffers**	Up to 1024 Kbytes	Up to 364 Kbytes	Up to 512 Kbytes	Up to 512 Kbytes	Up to 620 Kbytes
	Embedded flash for code and data	128 Kbytes to 2048 Kbytes	128 Kbytes to 1024 Kbytes	1024 Kbytes to 2048 Kbytes	128 Kbytes to 2048 Kbytes	64 Kbytes

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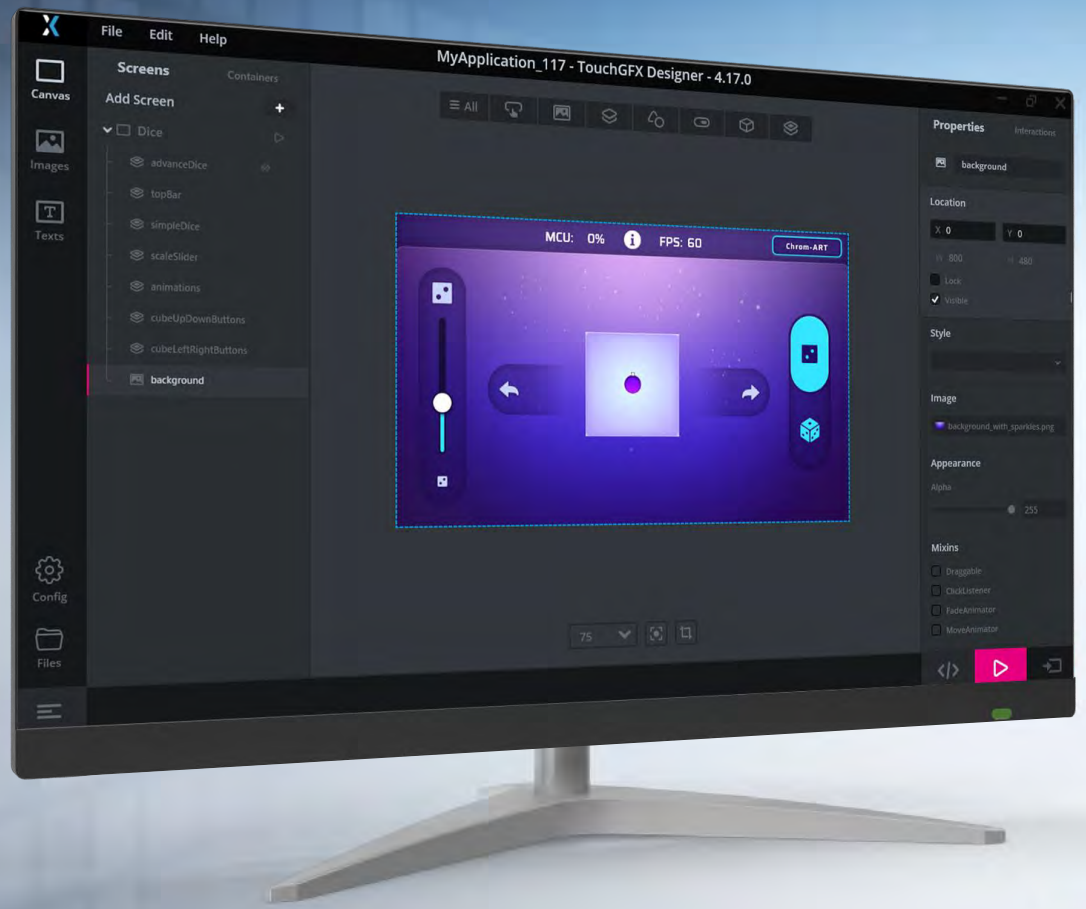
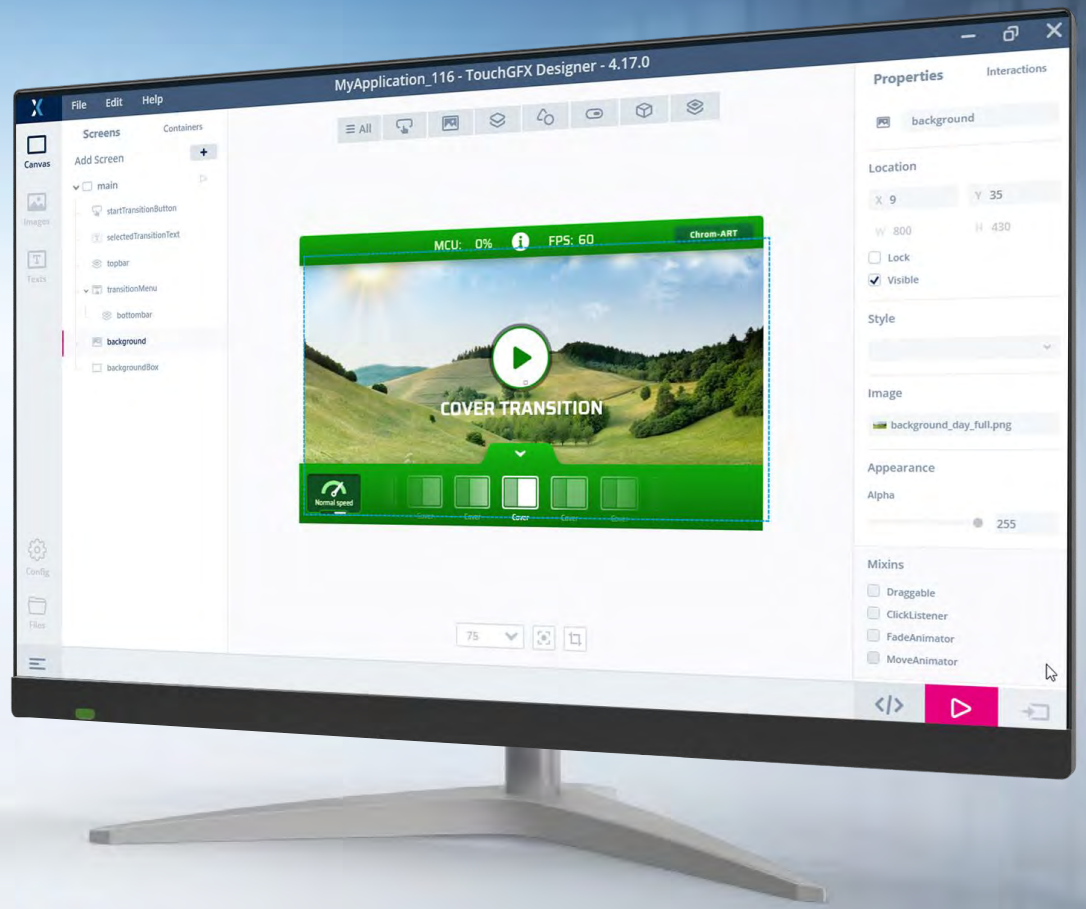
TouchGFX DESIGNER

Now with brand new User Interface with light and dark mode





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High-end UI with limited hardware requirements

TouchGFX GUI library

TouchGFX DESIGNER

PC GUI-builder and -simulator

TouchGFX GENERATOR

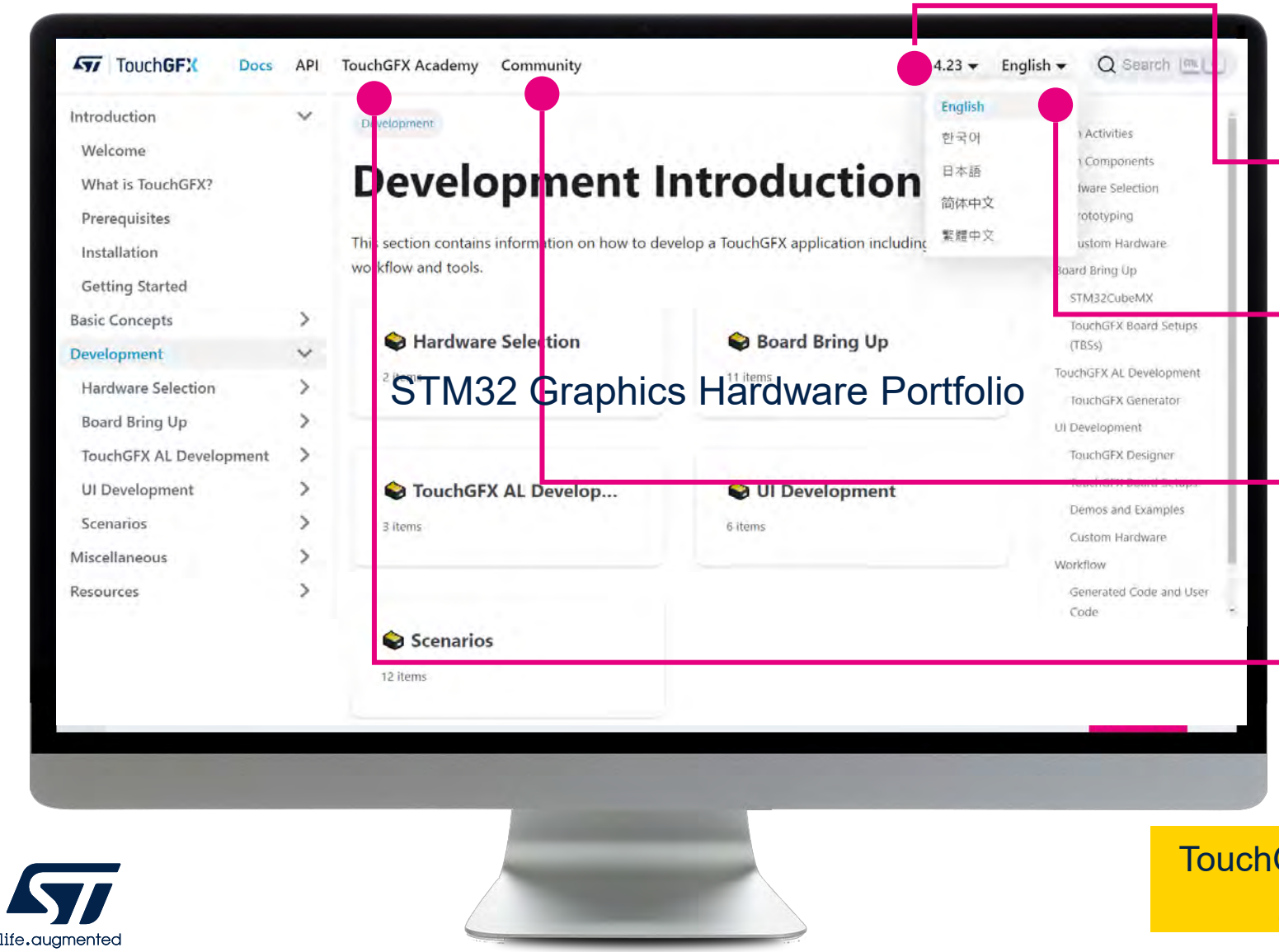
Configure and generate a TouchGFX project

TouchGFX ENGINE

Optimized and hardware accelerated graphics library

Delivered as an X-CUBE-TOUCHGFX Package

Get access to hours of training and detailed documentation



STM32 Graphics Hardware Portfolio

Select your TouchGFX **version**

Select your **language** (5 languages available)

Ask questions and learn from peers on the **Community**

Build up your TouchGFX competences at the **Academy**

TouchGFX documentation site (3000 pages): **https://support.touchgfx.com/**

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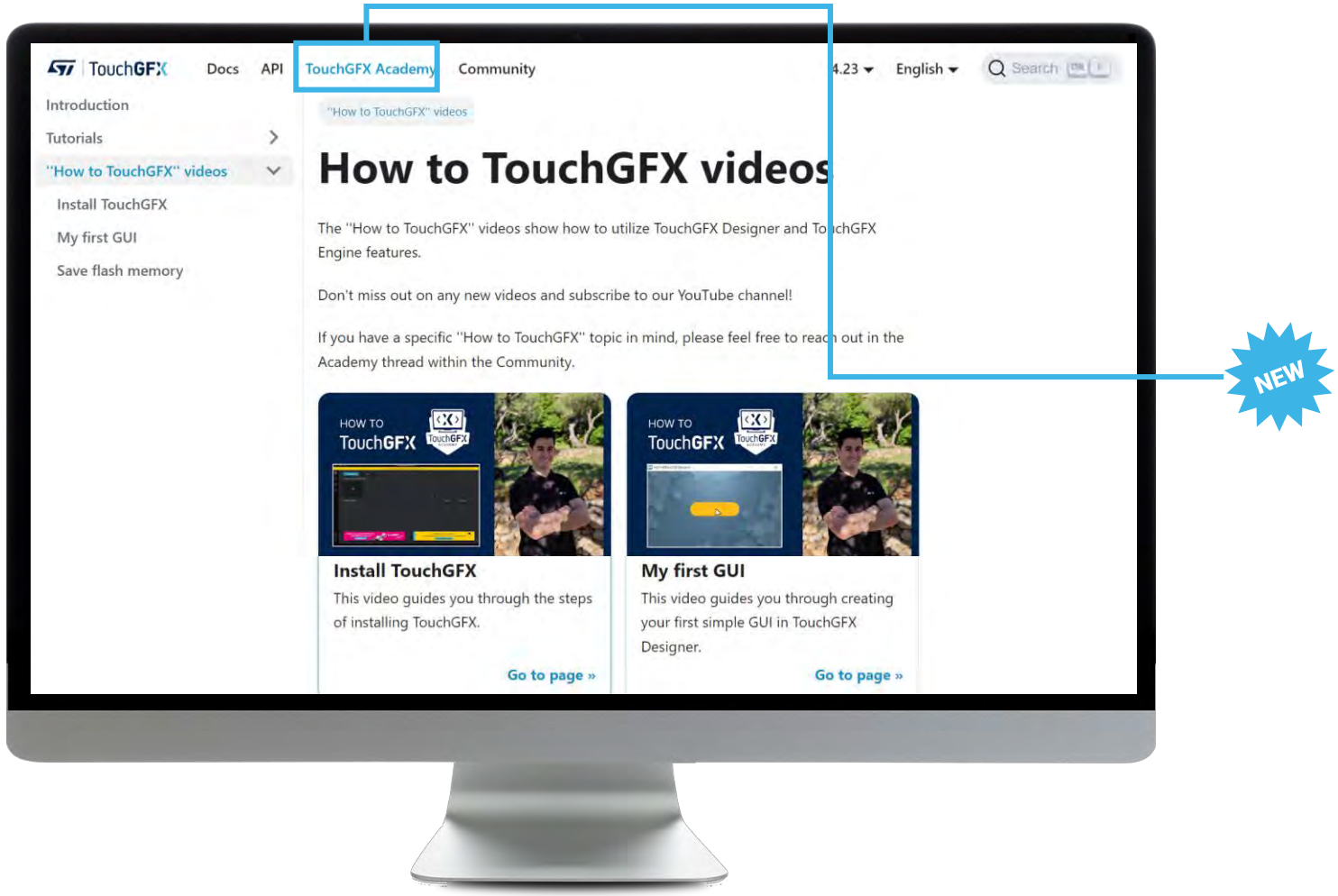
TouchGFX Academy



NEW

TouchGFX ACADEMY

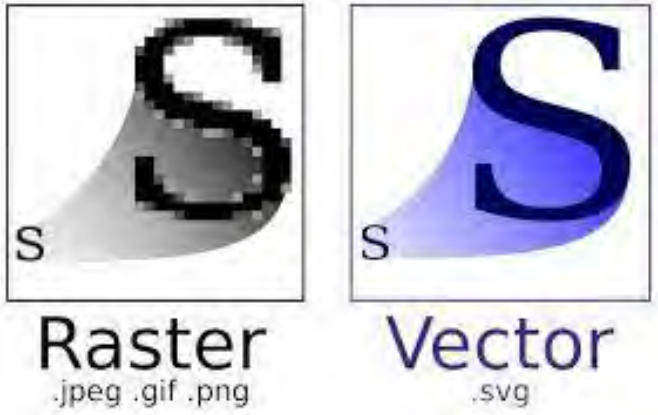
The place where the features and functionalities of TouchGFX are explained and showcased through practical examples

On documentation

YouTube

Vector graphics and its benefits

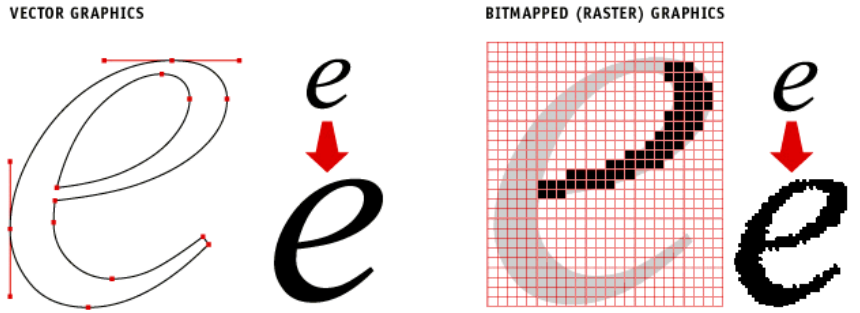
- Vector graphics ?
  - Allow creating images directly from geometric shapes, such as points, lines, curves and polygons
- Use cases
  - SVG (Scalable Vector Graphics) images
  - Vector fonts



Small memory footprint no matter the final size

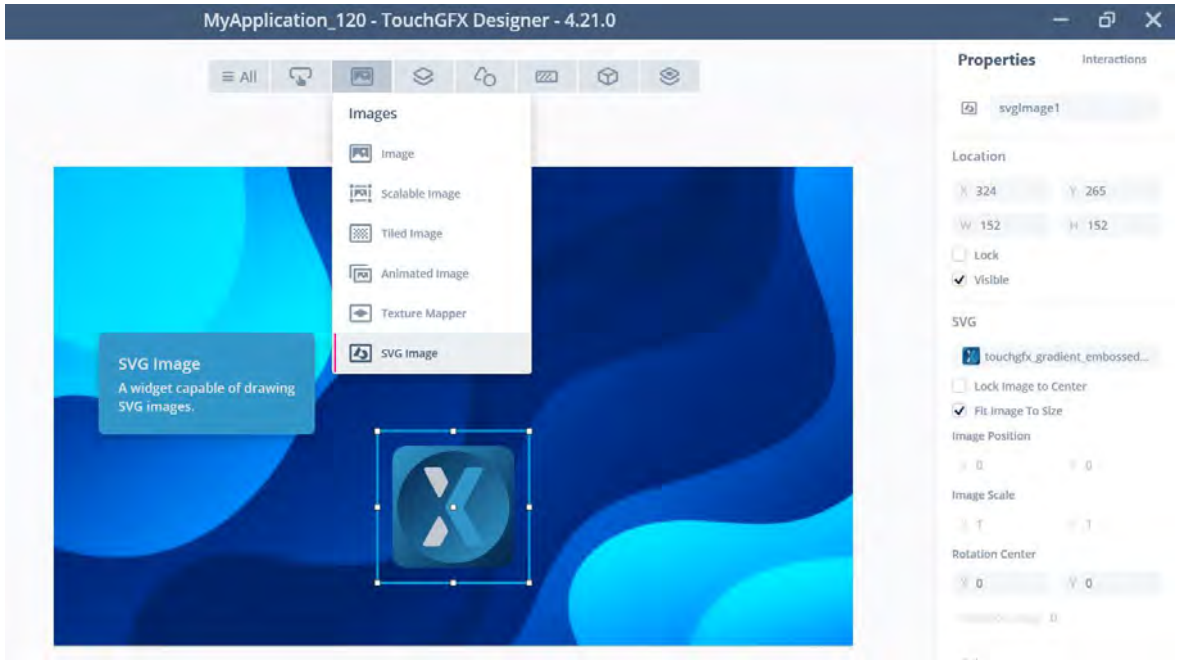
Image	Bitmap 200x200 RGB888	SVG	Memory saving
	120 Kbytes	4.2 Kbytes	**99.97%**
	120 Kbytes	350 bytes	**99.99%**

High quality zoom and rotation support



SVG (Scalable Vector Graphics) image widget

SVG Image widget

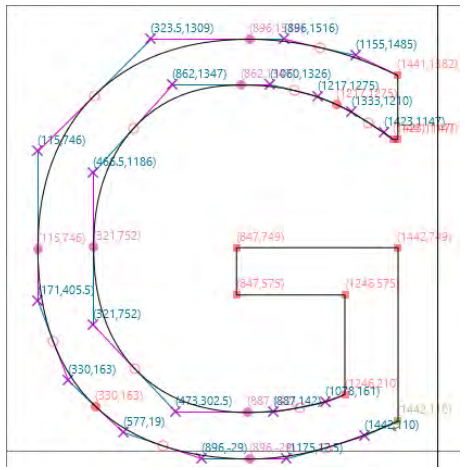


Selecting the new SVG image widget in TouchGFX Designer

- Support for SVG image format
  - Few SVG functions not supported.
- Adding vector graphics to TouchGFX
  - Addition to raster/bitmap graphics
- Use of NeoChrom GPU HW-acceleration if available,
  if not available then pure SW rendering

Vector fonts

- TrueType font vector data is extracted and added automatically to your project by TouchGFX.
- Vector-based fonts and bitmap-based fonts can be mixed in one application.
- Notes
  - Things that are traditionally related to vector-based fonts like animated rotation and scaling are not supported.
  - No new widget or animation. Texts are shown using the TextArea no matter if they are using vector font or bitmap font.



Huge potential for space saving!

Font size	"G" dimension/pixels	Bitmap size (bytes with 4bpp)	Vector size (approx. bytes)
20	14 x 14	98	160
30	21 x 22	242	160
40	27 x 32	448	160
Total		788 (100%)	160 (20%)
Saving		0%	**80%**

More time needed to draw vector fonts

MCU	HW acceleration	Operation	Font type	Render time (ms)
STM32F746	ChromART	"GGGG", size 30	Bitmap	**0,08**
STM32F746	No		Vector	**2,88**
STM32U599	NeoChrom GPU		Bitmap	**0,06**
STM32U599	NeoChrom GPU		Vector	**1,66**
STM32U5F9	NeoChromVG GPU		Vector	**0,80**

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Lossless image compression
For images under 256 colors

- TouchGFX can now find the best compression format for your L8 images to reduce the memory size while limiting reduction in rendering performance.
- Available compression formats:
  - L4 - Max 16 colors
  - RLE (Run-length encoding) Max 64 colors
  - LZW9 (Lempel-Ziv-Welch Compression Encoding) Max 256 colors
- L8 + additional selected compression can **reduce between 20% to 99% the memory size of the image**

Image	Bitmap size	Number of colors	Memory saving
	10 Kbytes (50x50)	32	**97.41%** (259 bytes)
	25.6 Kbytes (80x80)	193	**93.26%** (1.7 Kbytes)
	60 Kbytes (150x200)	128	**74.46%** (15.3 Kbytes)

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Lossless image compression
For RGB565, RGB888 and ARGB8888

- If L8 cannot be used, we have you covered with this latest compression algorithm !
- Huge **flash savings with up to 90 to 98%**
  - Less compression rate for complex images (many colors, gradients..)
- Applicable on all STM32 MCUs (H7, U5, H5, C0..)
- Limitations
  - Not direct applicable for rotating and scaling widgets (caching required)
  - Longer render time, depending on image complexity, MCU speed, flash access, HW acceleration.

ARGB8888 image 240 x 240 x 4 = 230.400 bytes

Flash saving	
Uncompressed	230KB
RGB Compressed	32KB
Memory saving	~ 86%

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Lossless image compression For RGB565, RGB888 and ARGB8888

Used Hardware:
STM32H7S78 DK
CPU 600 MHz
NeoChrom GPU

Image Type	Image Size	Image Format	Amount of Data (Bytes)	Compressed to: Bytes / %	Render Time Compressed (ms)	Render Time Uncompressed (ms)
White image	200 x 10	ARGB8888	8,000	208 / **2.6%**	-	-
Grey with gradients	200 x 10	ARGB8888	8,000	1,584 / **19.8%**	-	-
Round pink	32 x 32	ARGB8888	4,096	385 / **9.4%**	-	-
3 images for a slider	Total		20,096	2,177 / **10.8%**	0.75	0.27
Few color (yellow+shadow) image for button	240 x 50	ARGB8888	48,000	1,440 / **3.0%**	0.54	0.25
Advanced image with gradients	240 x 240	ARGB8888	230,400	21,197 / **9.2%**	2.13	1.15
Pictogram - simple image	100 x 100	ARGB8888	40,000	1,360 / **3.4%**	0.38	0.43
Photo – complex image	150 x 200	RGB565	60,000	24,360 / **40.6%**	1.32	0.27

The lower the percentage the better the compression

How much can you save memory in your GUI project ?

Use TouchGFX build-in features to develop advanced GUIs requiring **low flash usage**

Bitmap compression:
- L8 image format
- Compression of L8

Vector operations:
- SVG
- VG Fonts

Full demo – Savings:
- Bitmap implementation: 10,5MB
- Flash-limiting implementation: 800 KB
- **Flash Savings: 92%**

TouchGFX reference app running on STM32U5G9 proven advanced GUI with only internal memory.

Full project available in TouchGFX Designer

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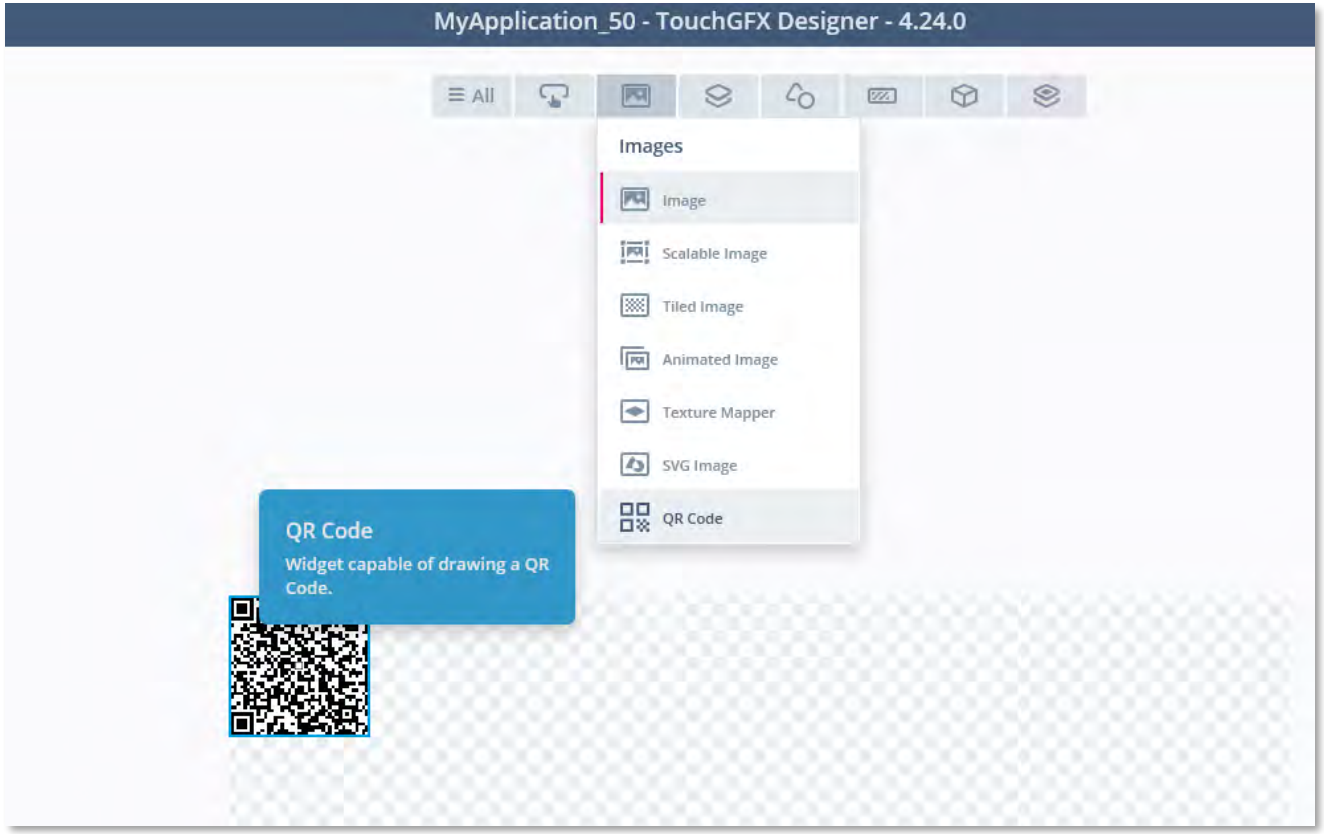
QR code widget

QR Code Widget

- Applications where you want to dynamically generate QR Codes on run time
  - Encoding strings and binary data into a QR code
    - URL's for pointing to a specific webpage

- QR code generator. It can generate up to a Level 40 QR code (177 modules x 177 modules) on the fly and draw it in the frame buffer, to be displayed on the screen.



QR code widget documentation page.

For more information

- TouchGFX download page
- TouchGFX documentation
- TouchGFX forum
- TouchGFX blog post
- STM32 Graphics demos YouTube playlist
- STM32 Graphics offer & Announcements YouTube playlist
- TouchGFX technical videos YouTube playlist
- STM32 Graphics Partners YouTube playlist
- STM32 MPU with Qt – Wiki page

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STM32 Wireless solution

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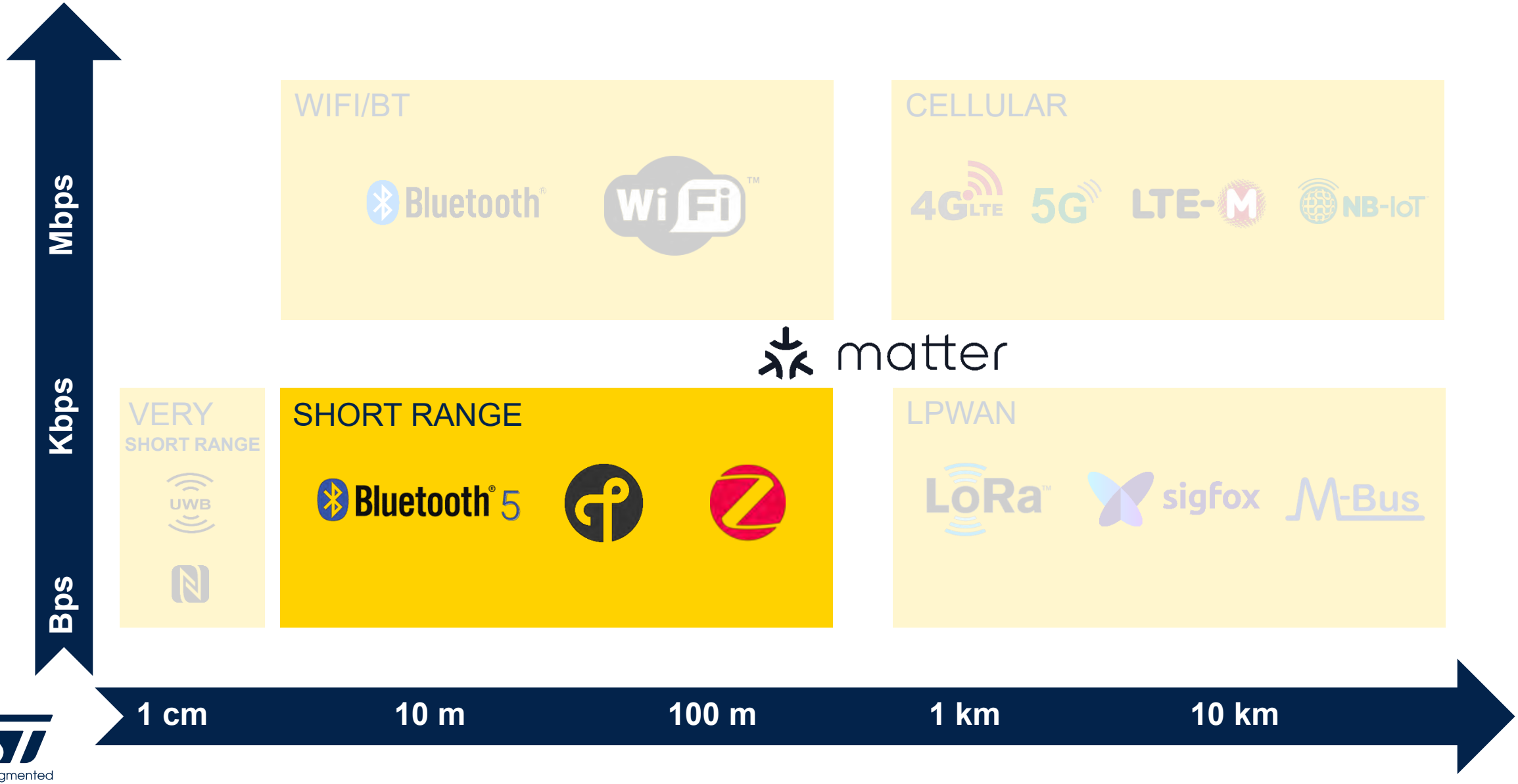
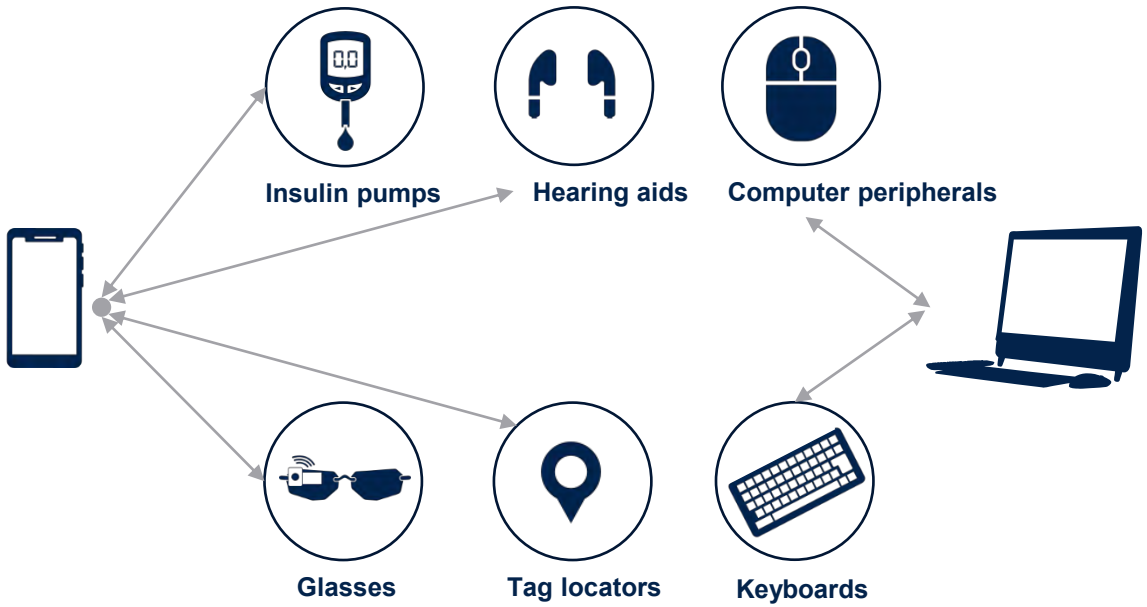
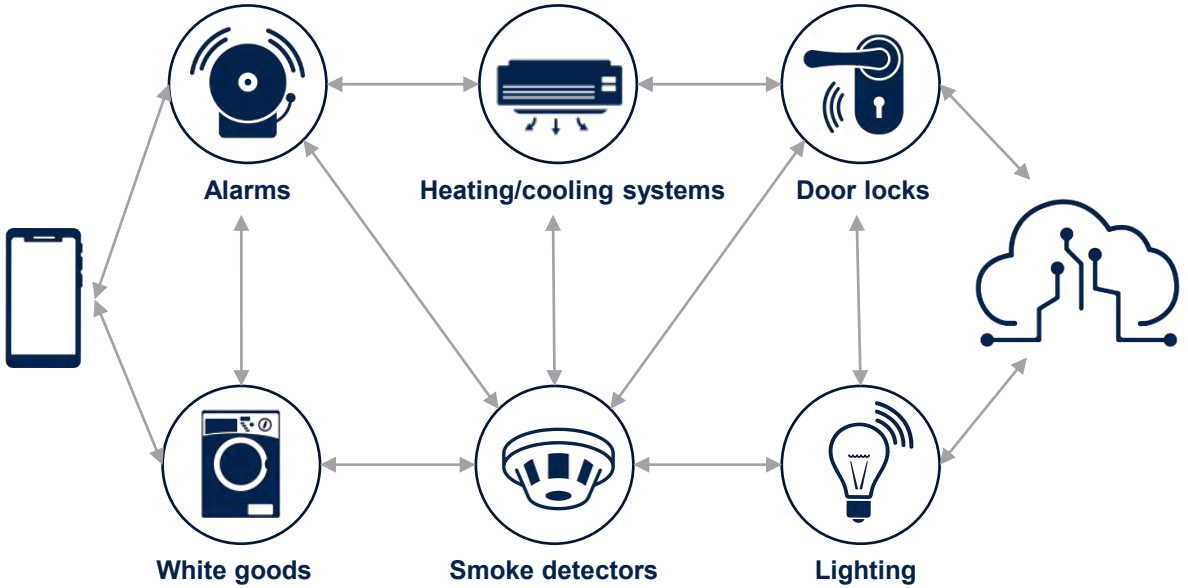
Communication technologies



Bluetooth® technology is all around us





P2Point or P2Multi-Comm. devices

Connected to smartphones, laptops…
Mostly battery powered

Bluetooth®

Proprietary protocols

Mesh communication devices

Home automation, Industry 4.0, consumer power supply and/or battery powered

Bluetooth®

matter

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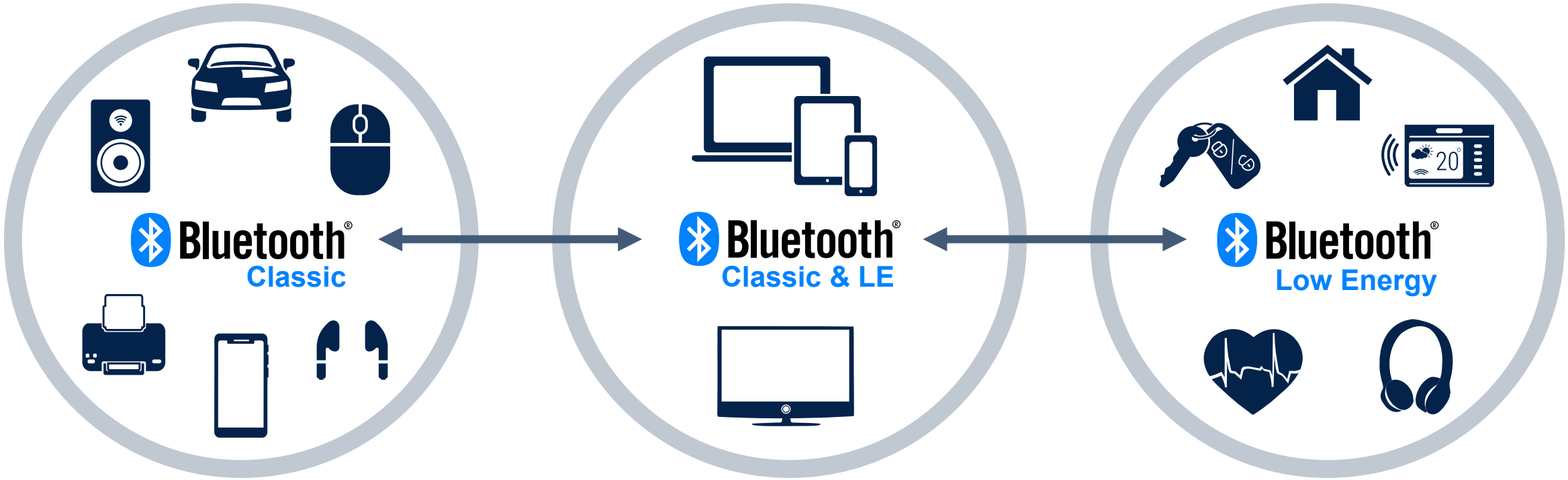
Bluetooth® Classic vs Bluetooth® Low Energy



Wireless devices streaming **rich content**

Devices that can connect with **both** Bluetooth Classic and Bluetooth Low Energy

Sensor devices, accessories with **low data-rate**, but **high battery** lifetime requirements

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What is Bluetooth® Low Energy?

Low-power wireless technology focused on IOT

Low-power wireless technology

Introduced in **2010** by the Bluetooth® Special Interest Group (**Bluetooth® SIG**) as part of the Bluetooth **4.0**

Short range wireless operates in the unlicensed **2.4 GHz** ISM band

Multiple communication topologies : from **point-to-point** to **broadcast** and **mesh**

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Applications

Smart home
Lights, thermostats, sensors

Fitness tracking
Smartwatches

Electronic Shelf Label
Pricing and product info

Digital key
Smartphones as secure key

Item Finding
Personal property tags

Audio
Broadcast, hearing aids

PoI Information
Proximity marketing

Indoor positioning
Wayfinding

RTLS
Asset tracking

Networked Lighting Control

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Applications

Smart home
Lights, thermostats, sensors

Fitness tracking
Smartwatches

Electronic Shelf Label
Pricing and product info

Digital key
Smartphones as secure key

Item Finding
Personal property tags

2017 **v5.0** Mesh networking

2019 **v5.1** Direction Finding

2020 **v5.2** LE Audio

2021 **v5.3** Reliability, Energy efficiency, Security

2023 **v5.4** Periodic Advertising with Responses

Audio
Broadcast, hearing aids

PoI Information
Proximity marketing

Indoor positioning
Wayfinding

RTLS
Asset tracking

Networked Lighting Control

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Architecture

Bluetooth® LE Stack

Apps

- Real application code
- MCU flash memory

Host

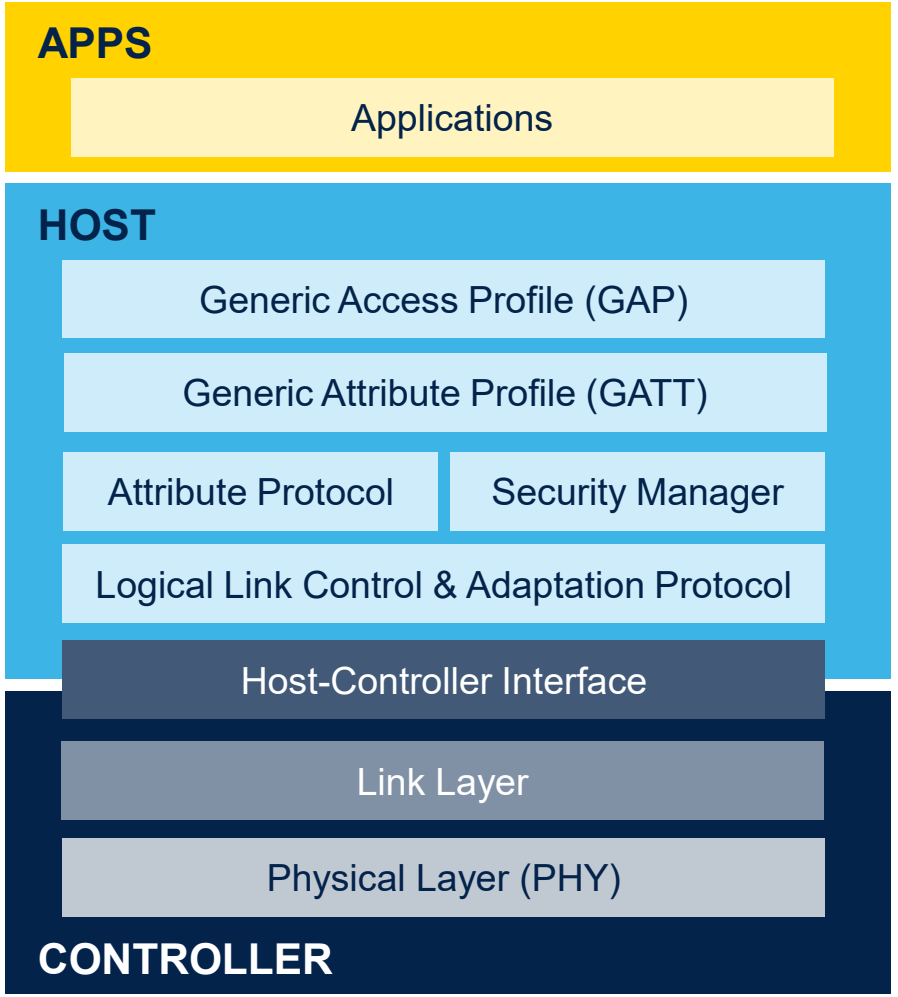
- How to access data
- Operating system

Controller

- Radio operations
- System on a chip (SoC)

Host and controller may be implemented in physically **separate components**, with a standard interface : **Host Controller Interface** (HCI)

→ Allows **different manufacturers**



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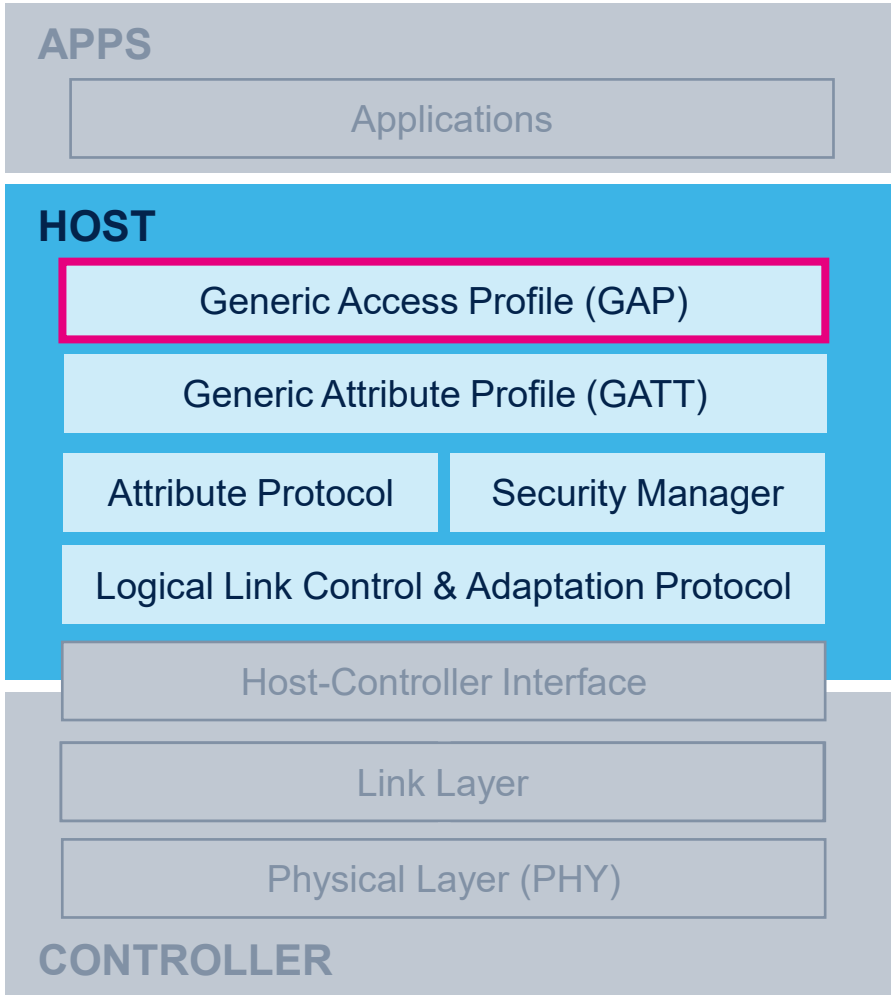
Generic Access Profile (GAP)

Defines and manages advertising and connection

- **Broadcasting**
  - o Broadcaster : device broadcasts public advertising data packets
  - o Observer : device that listen to the data in the advertising packets sent by the broadcaster
- **Connecting**
  - o Peripheral : can connect with a central device. After connecting, stop broadcast data
  - o Central : sends request connection data packet to the peripheral device.



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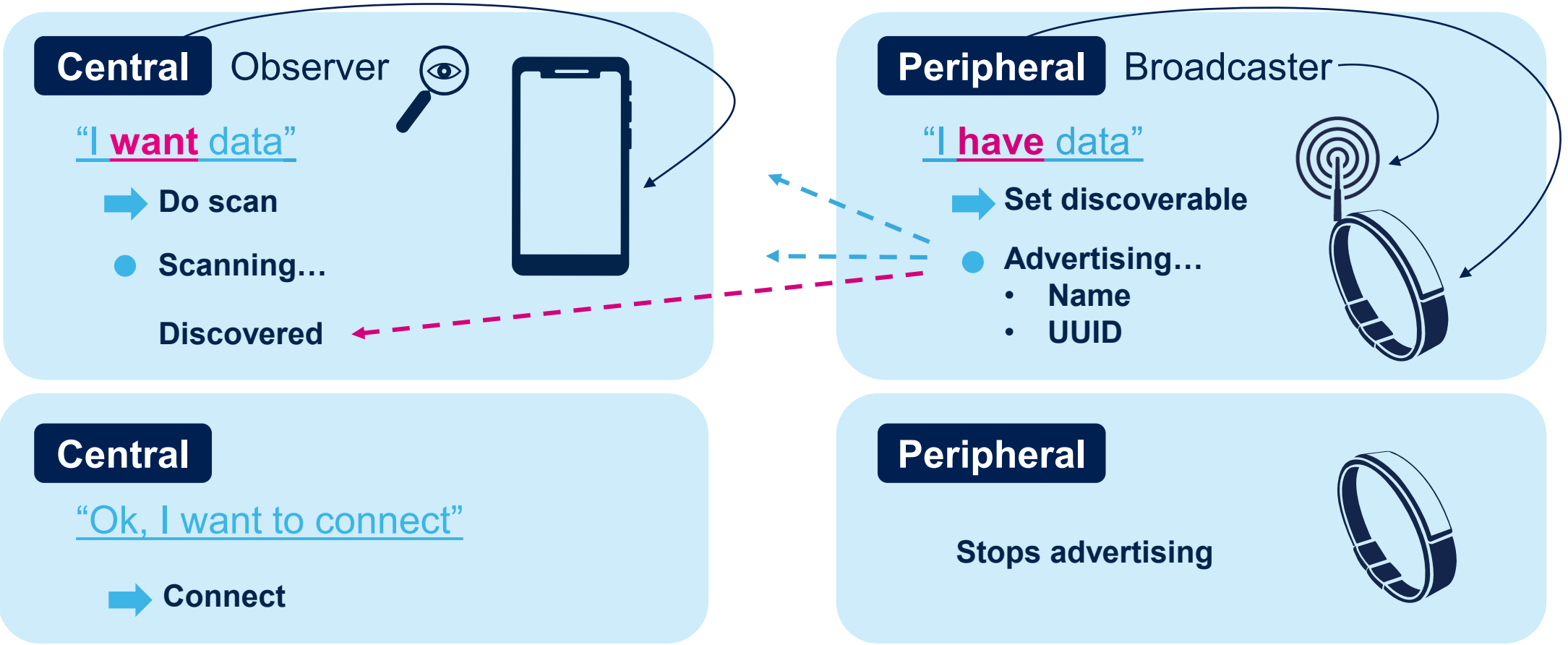
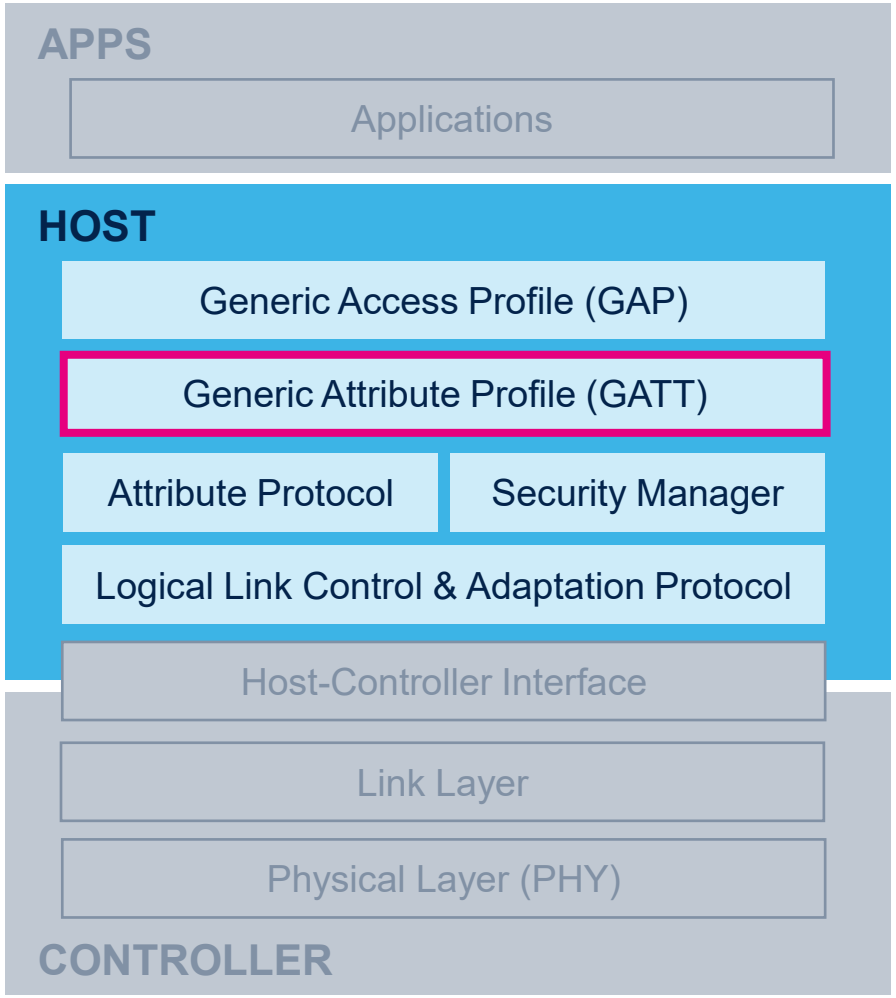
Generic Access Profile (GAP)



Generic Attribute Profile (GATT)

Defines and manages in/out data exchanges

- GATT reuses **ATT** to describe how data is exchanged from two connected devices
- **Client**
  - Sends request to the GATT server. Client can **read** and/or **write attributes** found in the server
- **Server**
  - One of the main roles of the server is to **store** attributes. Once the client makes a request, the server must make the attributes available.



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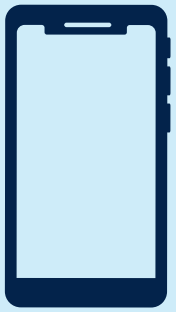
Generic Attribute Profile (GATT)

Central **GATT Client**

"Ok, what can you do for me?"

- **Discover services**
- **Discover characteristics**



- **Read characteristic**
- **Enable notifications**
- **…**

connected

Peripheral **GATT Server**

Bluetooth® SIG Heart Rate Profile

Service Heart Rate 0x180D

Characteristic Heart Rate Measurement	N	0x2A37
Characteristic Body sensor Location	R	0x2A38
Characteristic Heart Rate Control Point	W	0x2A39

Service Device Information 0x180A

Characteristic Manufacturer Name	R	0x2A29

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The STM32 portfolio

Five product categories

Wireless MCU

Short- and long-range connectivity

Ultra-low-power MCU

Mainstream MCU

High-performance MCU

Embedded MPU

32- and 64-bit microprocessors





Enabling edge AI solutions

Scalable security

MPU portfolio

MCU portfolio

STM32 MCU 2.4 GHz portfolio

STM32WB series

- Dual core & security (Arm® Cortex® -M4 / -M0+)
- Up to 1 Mbyte of flash memory / 256 Kbytes of RAM

MCUs: STM32WB55 | STM32WB35 | STM32WB15

Modules: STM32WB5M | STM32WB1M

5.4 & Mesh

matter

STM32WBA series

NEW

STM32WBA54/55

STM32WBA52

5.4

matter*

- Arm® Cortex® -M33/TrustZone® 100 MHz
- 1 Mbyte of flash memory / 128 Kbytes of RAM
- Up to +10 dBm output power

*Matter Thread RCP Mode only

BlueNRG series

- Arm® Cortex® -M0/M0+
- Up to 256 Kbytes of flash memory / 64 Kbytes of RAM

System on Chips: BlueNRG-1 | BlueNRG-2/2N | BlueNRG-LP | BlueNRG-LPS

Module: BlueNRG-M2SP/SA

5.2 to 5.4 & Mesh

EVOLUTION

STM32WB0 series

STM32WB09

5.3

- Arm® Cortex® -M0+ at 64 MHz
- 512 Kbytes of flash memory / 64 Kbytes of RAM
- Bluetooth® Low Energy 5.3 (long range, 2 Mbps, Advertising ext, AoA/AoD, Isochronous channel)
- Up to +8 dBm of output power

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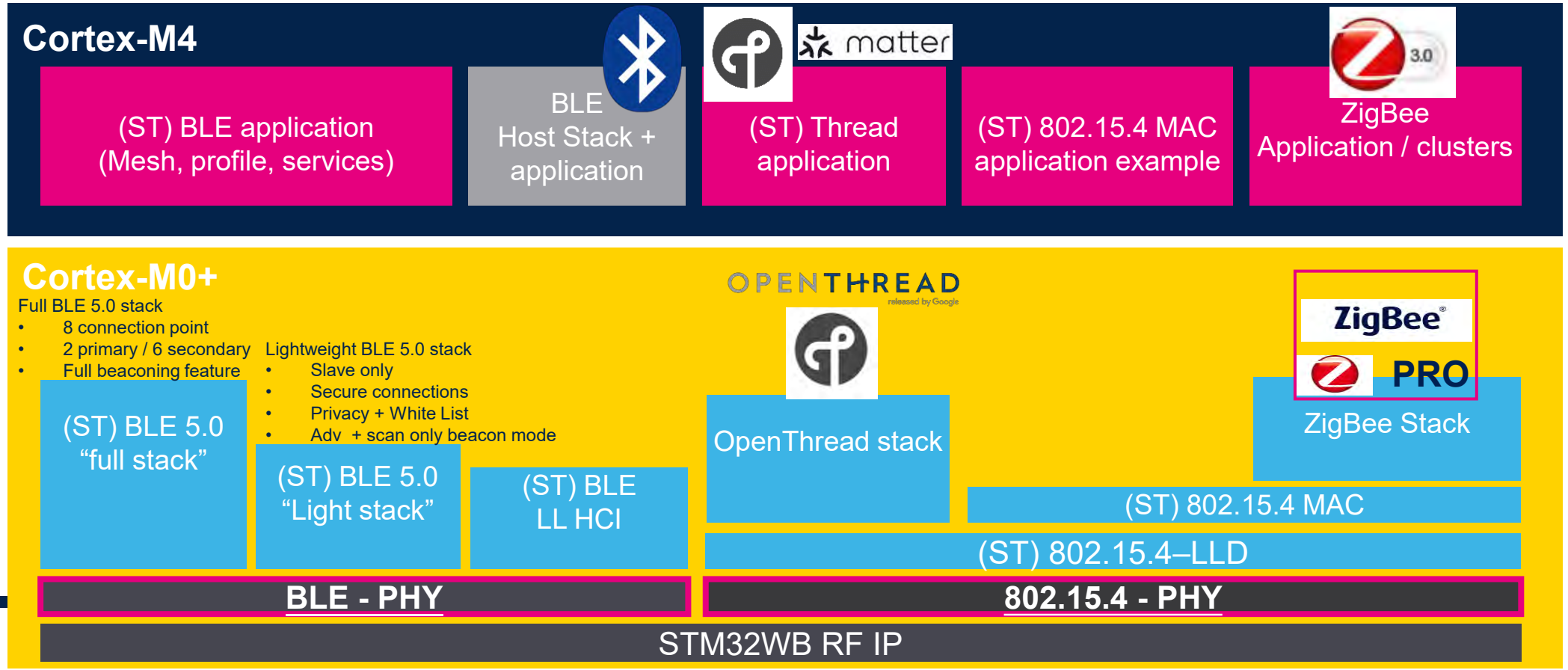
Free multiple protocol stacks and reference package

Binary
Source code
Private
Hardware IP



STM32WB55	STM32WB35	STM32WB15
BLE 5.2/Zigbee 3.0 Open Thread/Matter proprietary (HCI, MAC, LLD) /802.15.4 Multiprotocols (BLE/Zigbee, BLE/Thread)	BLE 5.2 Zigbee 3.0 Open Thread proprietary (HCI, MAC, LLD) /802.15.4	BLE 5.2 proprietary (HCI, LLD) /802.15.4

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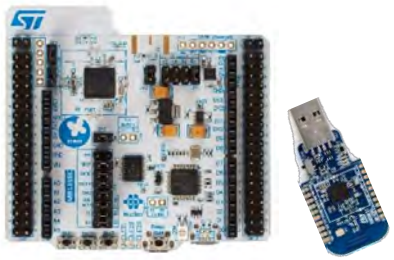
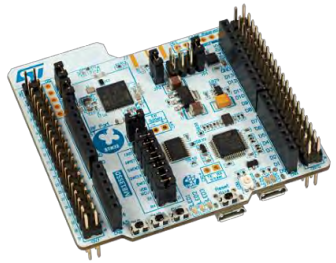
Prototyping made as easy as 1,2,3



P-NUCLEO-WB55

STM32WB5MM-DK

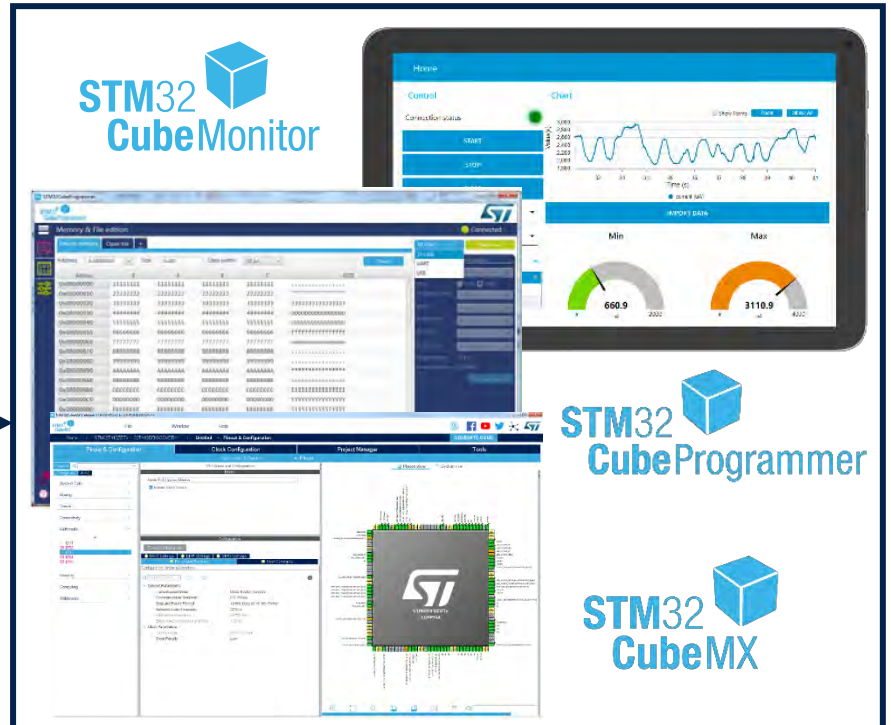


NUCLEO-WB55RG
NUCLEO-WB15CC

B-WB1M-WPAN1

Hardware
Evaluation Pack, Nucleo-64 board, Discovery Kit

STM32WB



STM32CubeMX/STM32CubeWB/
STM32CubeProg & STM32CubeMonitor
Code generation
Power calculation

STM32 Cube

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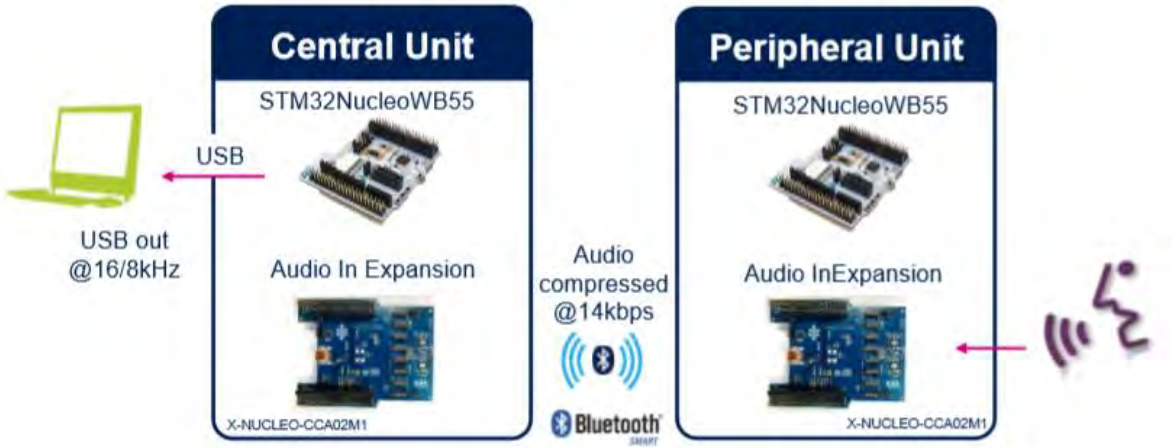
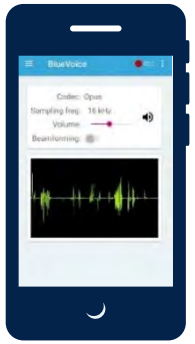
Advanced functionalities

Audio - Voice & streaming

Full-duplex audio streaming over Bluetooth LE 5.3 using Opus codec
STM32Cube function pack for STM32WB MCU: FP-AUD-BVLINKWB1



STM32WB Nucleo development board
+
Digital MEMS microphones Expansion board



Sensor fusion & activity recognition

Bluetooth LE connectivity with environmental and motion sensors
STM32Cube function pack for STM32WB MCU: FP-SNS-MOTENVWB1

STM32WB Nucleo-64 development board
+
Motion MEMS and Environmental Sensor Expansion board

Both packages are compatible with STBLESensor app for iOS and Android

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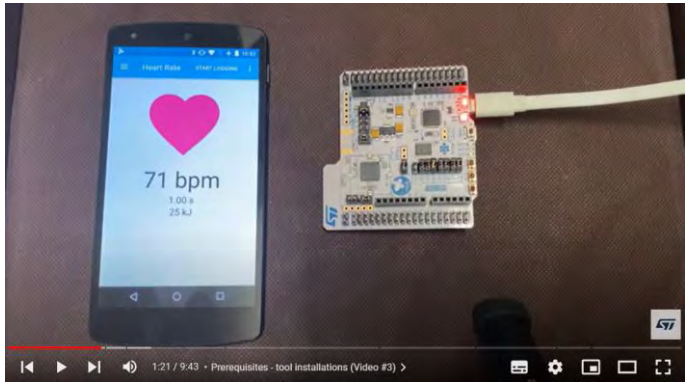
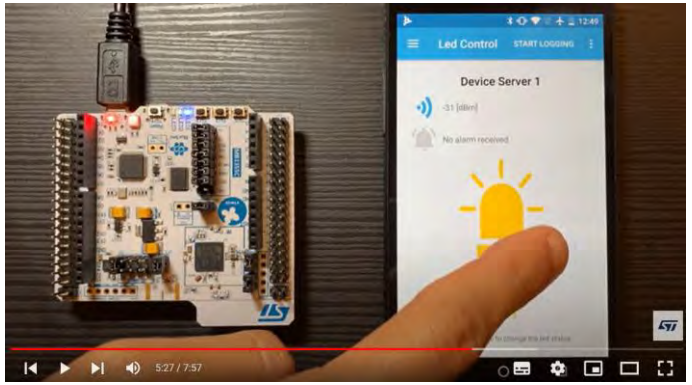
STM32WB getting started series

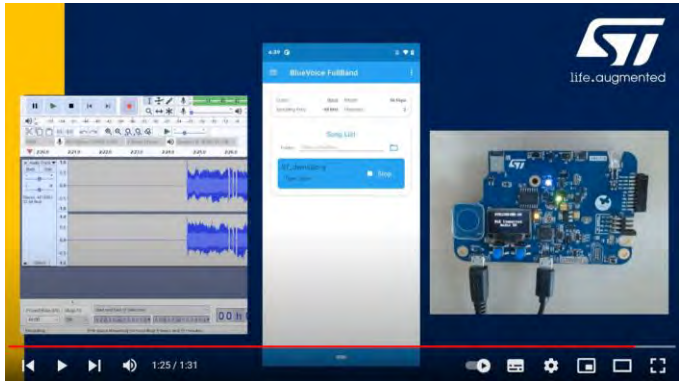


Heartrate monitoring

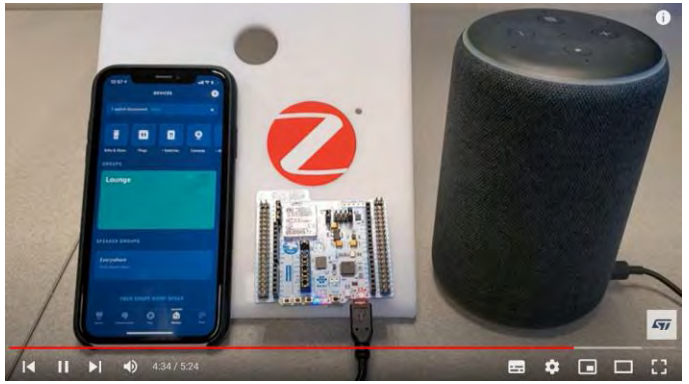


Peer to peer

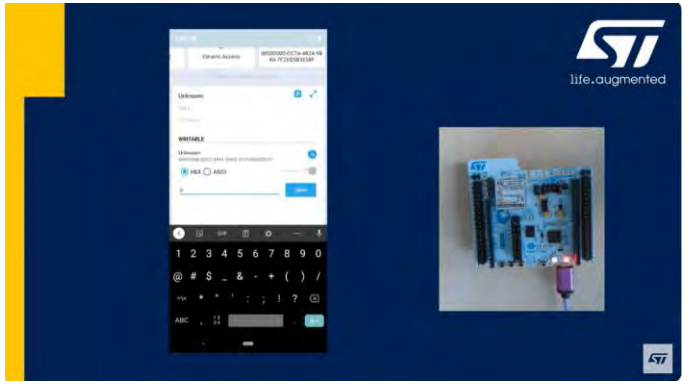
OTA update



Music/Voice streaming

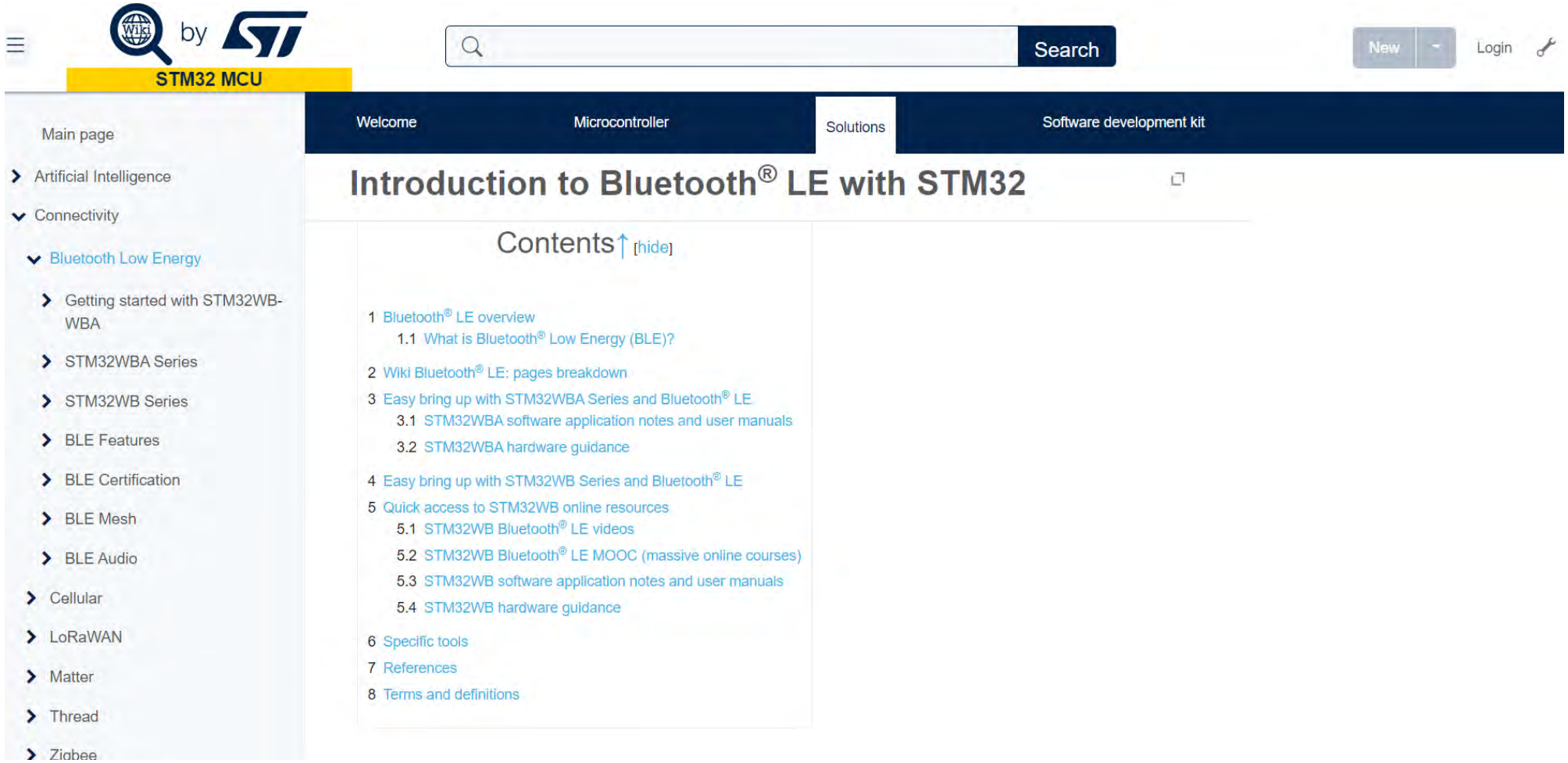


Zigbee w/ Amazon echo



Receiving data from phone

Wiki pages for connectivity



WiKi : (link)

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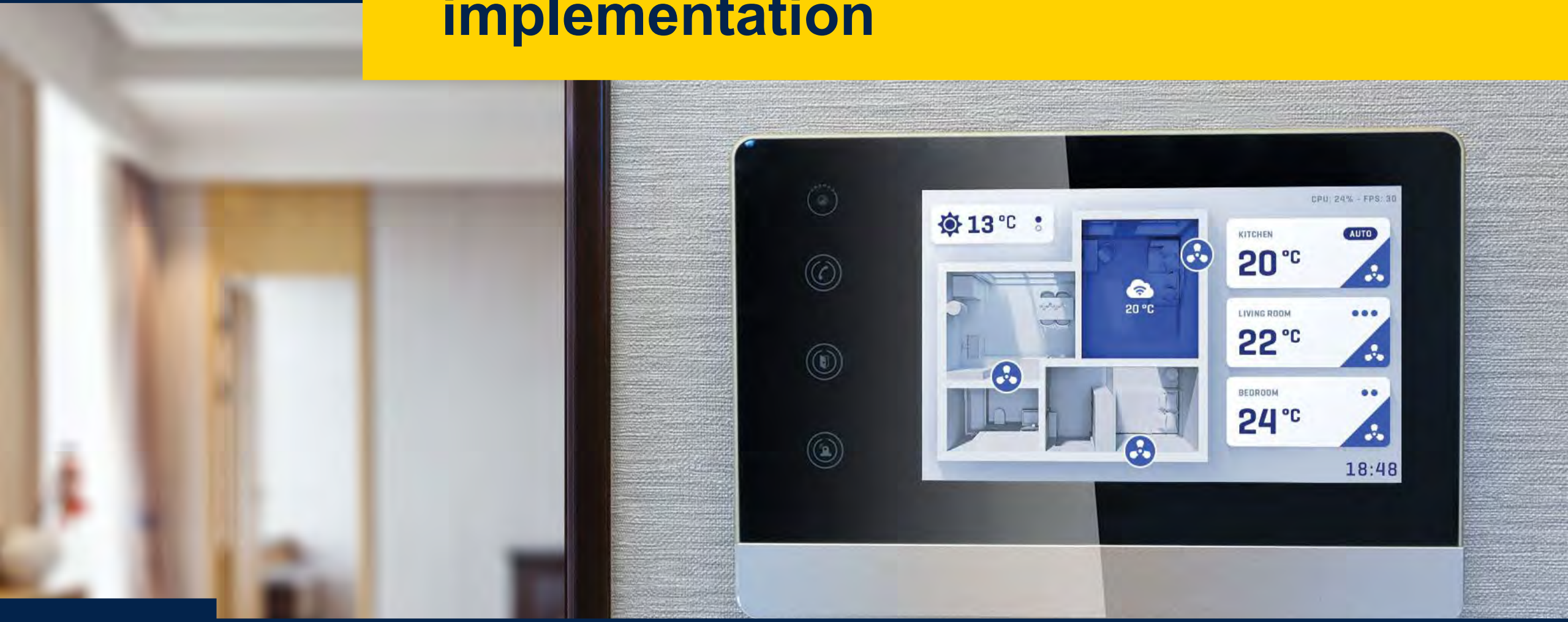
“Graphics with Wireless” implementation



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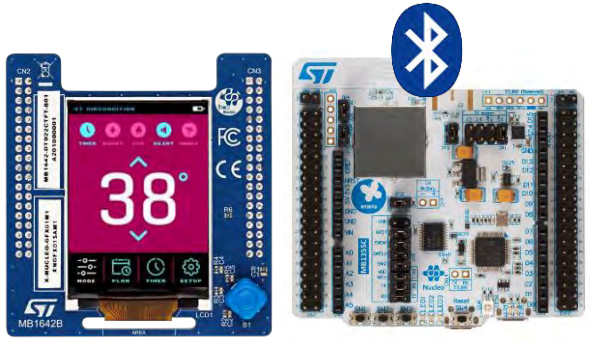
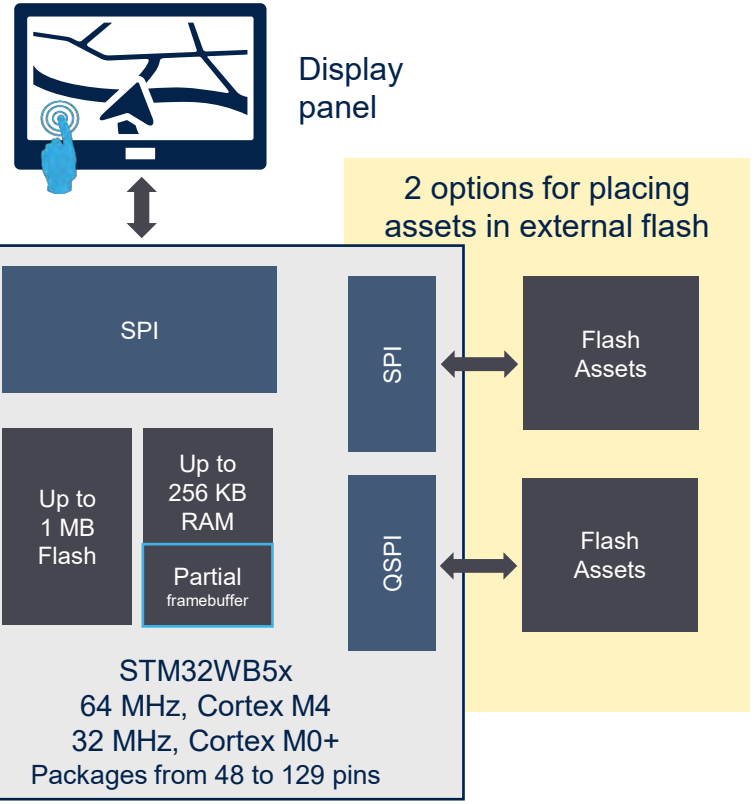
Entry-level graphics coupled with BLE STM32WB55RG

Displays up to 4,3” Up to 480x272

Resources

- **NUCLEO-WB55RG + X-NUCLEO-GFX01M2**
  - 2.2” SPI QVGA 320x240 display
- **TouchGFX Designer**
  - UI demo available
  - TouchGFX Board setup
  - Note:
    TouchGFX GUI footprint starting from 30kB flash and 16kB RAM (including partial frame buffer)



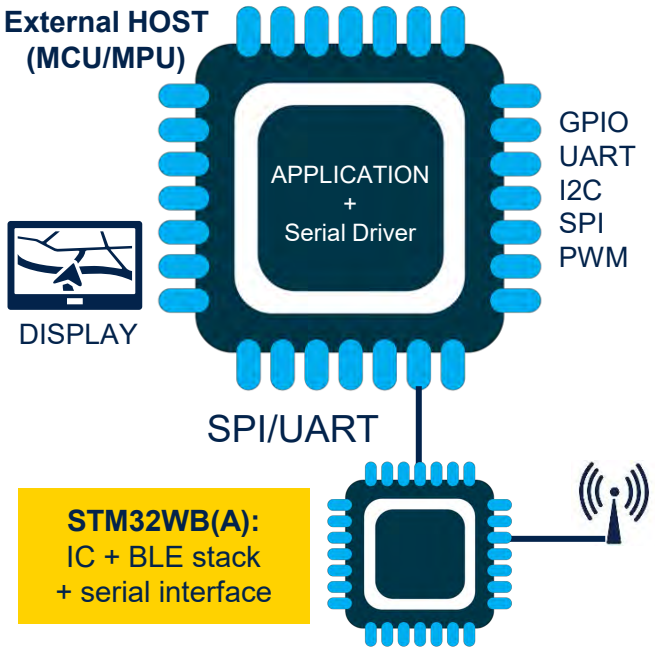


No external RAM due to partial framebuffer

GFX Wireless Applicative Topologies

NETWORK PROCESSOR

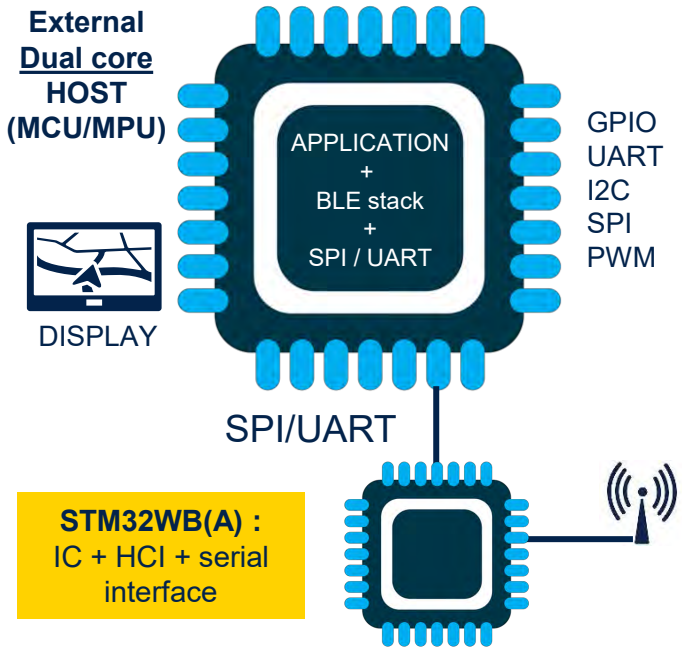
Radio link added through a simple and standard **serial interface**



Radio as a simple plug-in on a standard serial interface

RADIO CO-PROCESSOR

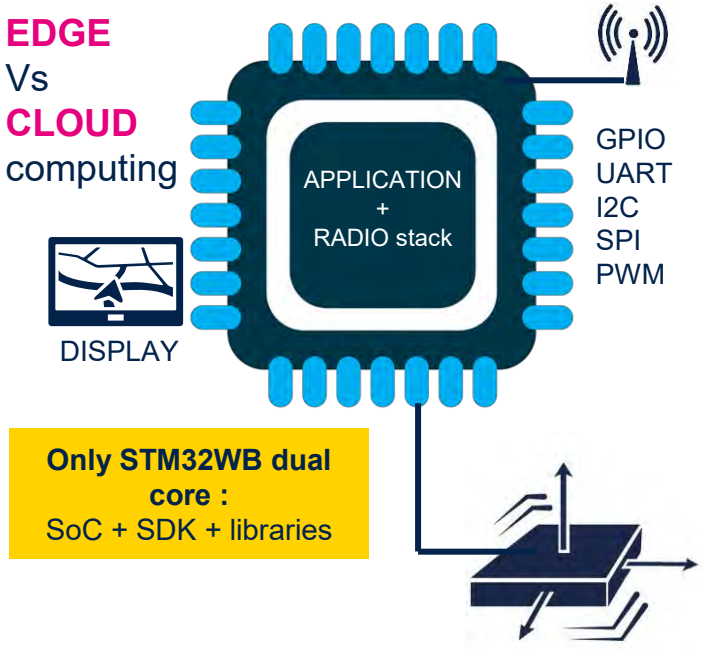
Application is running over a dedicated MCU along with the **BLE stack**



Specific integration of radio middleware/driver required

APPLICATION PROCESSOR

Data acquisition, **processing** and **radio connectivity** in a single-chip



Full code ownership in all-in-one image (data, processing, radio)

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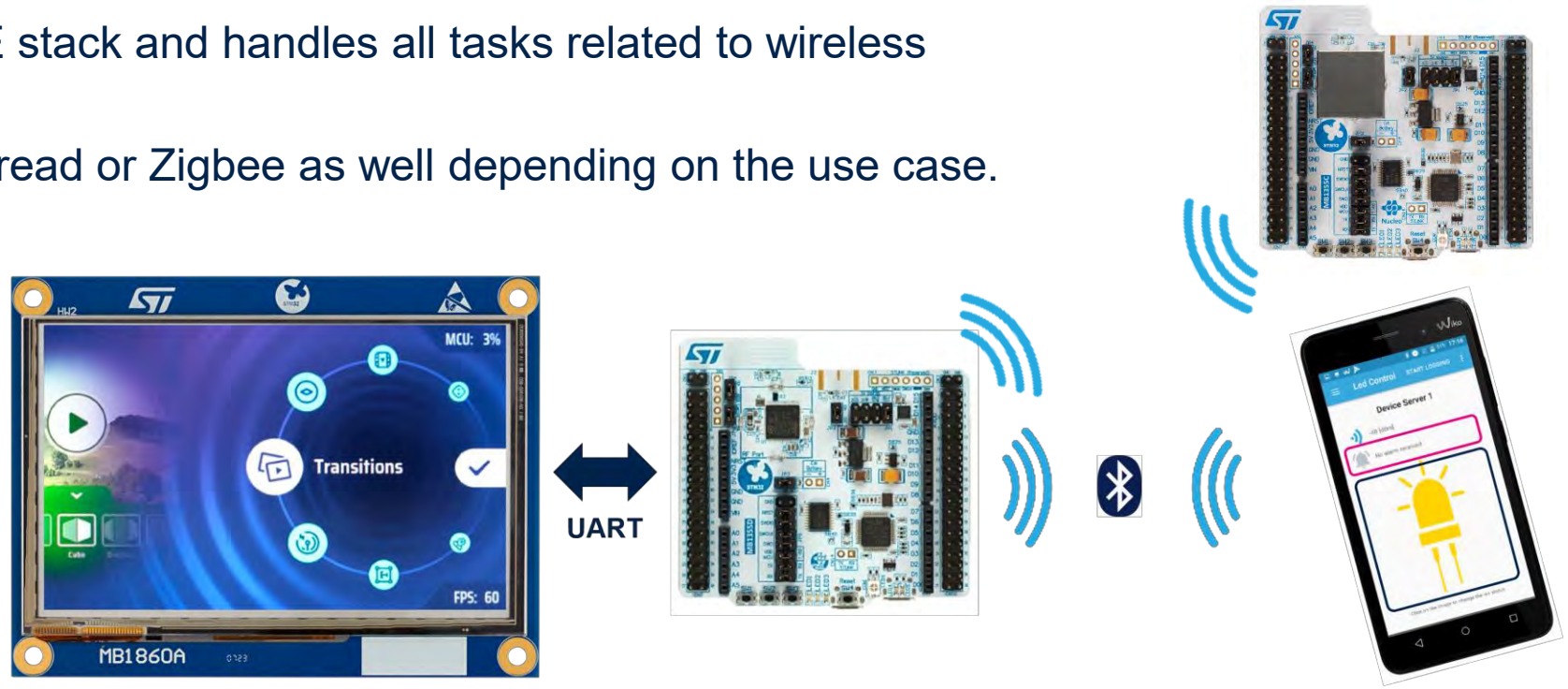
Combining a host and a network processor to add wireless capabilities to a UI project

- Demo structure for the challenge
  - STM32WB acts as a BLE transceiver connected to the main controller being the STM32U5G9J-DK2
    - STM32U5 drives the LCD and runs the graphic framework.
    - STM32WB runs the BLE stack and handles all tasks related to wireless connectivity.
    - STM32WB could run Thread or Zigbee as well depending on the use case.



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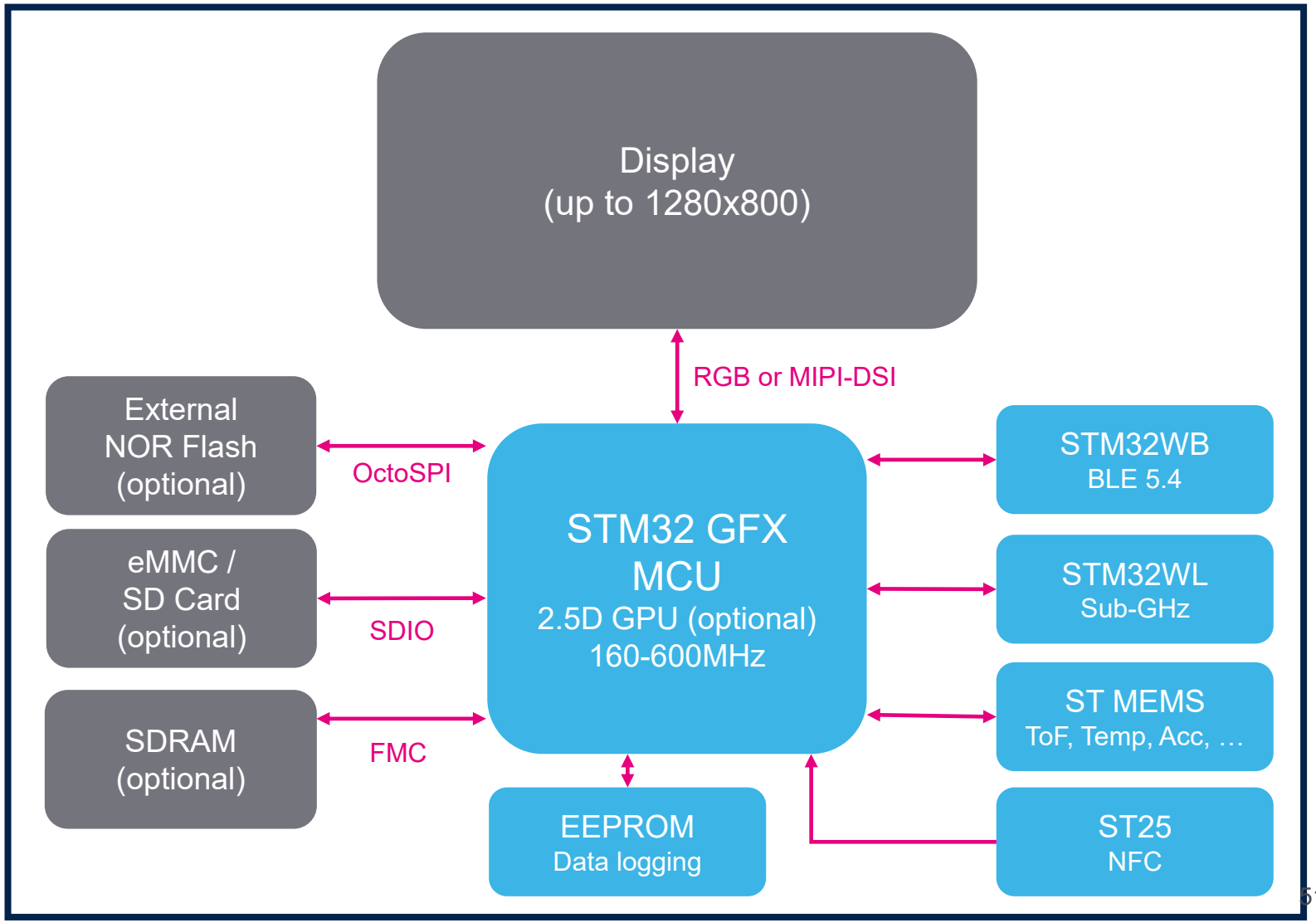
Different technologies into a single project

- ST's rich portfolio allows users to **combine different technologies** into one single project.
- With ST, you can make a feature-rich solution with graphics, wireless and sensing all together.
- Enjoy better prices when selected 2 or more MCUs.



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