TECHNICAL DEEP DIVE

Anki Vector

A LOVE LETTER TO THE LITTLE DUDE

AUTHOR RANDALL MAAS

OVERVIEW This is fascicle explores how the Anki Vector was realized in hardware and software.

RANDALL MAAS has spent decades in Washington and Minnesota. He consults in embedded systems development, especially medical devices. Before that he did a lot of other things… like everyone else in the software industry. He is also interested in geophysical models, formal semantics, model theory and compilers.

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Preface

The Anki Vector is a charming little robot – cute, playful, with a slightly mischievous character. It is everything I ever wanted to create in a bot. Sadly Anki went defunct shortly after releasing Vector.

This book is my attempt to understand the Anki Vector and its construction. The book is based on speculation. Speculation informed by Anki's SDKs, blog posts, patents and FCC filings; by articles about Anki, presentations by Anki employees; by PCB photos, and foo'd hardware from others; and by experience with the parts, and areas.

1.1. CUSTOMIZATION / REPAIRS AND PATCHING

What can be customized – or patched – in Vector?

- The firmware in the main processor, that will be dicussed in the rest of the document
- The base-board is not field updatable, without expertise. The STM32F030 can be extracted with a ST-Link ($25), and the the firmware can be disassembled — the microcontroller is conducive to this. Shy of recreating the firmware, the patches replace a key instruction here and there with a jump to the patch, created in assembly (most likely) code to fix or add feature, then jump back. (STM32's come with a boot loader, but the stlink is easier and inexpensive.)
- The cube firmware can be updated, but that seems both hard and not useful.
- The parts on the PCBAs, if identified, can be perhaps be replaced (for those with the soldering equipment). Saving and reselling some of the PCBAs from broken robots.
- Project Victor has done some work to locate a replacement LCD

2. ORGANIZATION OF THIS DOCUMENT

- CHAPTER 1: PREFACE. This chapter describes the other chapters.
- CHAPTER 2: OVERVIEW OF VECTOR'S ARCHITECTURE. Introduces the overall design of the Anki Vector.

PART I: ELECTRICAL DESIGN.

- CHAPTER 3: VECTOR'S ELECTRICAL DESIGN. A detailed look at the electrical design of Vector.
- CHAPTER 4: ACCESSORY ELECTRICAL DESIGN. A look at the electrical design of Vectors accessories.

PART II: BASIC OPERATION.

- CHAPTER 6: COMMUNICATION. A look at the communication stack in Vector.
- CHAPTER 7: BLUETOOTH LE. The Bluetooth LE protocol that Vector responds to.
- CHAPTER 8: CLOUD. A look at the electrical design of Vectors accessories.

REFERENCES AND RESOURCES. This provides further reading and referenced documents.

APPENDICES: The appendices provides extra material

- APPENDIX A: ABBREVIATIONS, ACRONYMS, & GLOSSARY. This appendix provides a gloss of terms, abbreviations, and acronyms.
- APPENDIX B: TOOL CHAIN. This appendix lists the tools known or suspected to have been used by Anki to create, and customize the Vector, and for the servers. Tools that can be used to analyze vector
- APPENDIX C: BLUETOOTH LE PROTOCOLS. This appendix provides information on the Bluetooth LE interfaces to the companion Cube, and to Anki Vector
- APPENDIX D: SERVERS. This appendix provides the servers that the Anki Vector and App contacts
- APPENDIX E: PHRASES. This appendix reproduces the phrases that the Vector keys off of.
- APPENDIX F: FEATURES. This appendix enumerates the Vector OS "features" that can be enabled and disabled.
- APPENDIX G: FILE SYSTEM. This appendix lists the key files that are baked into the system.

Note: I use many diagrams from Cozmo literature. They're close enough

CHAPTER 2

Overview of Vector

Anki Vector is a cute, palm-sized robot; a buddy with a playful, slightly mischievous character. This chapter is provides an overview of Vector:

- Overview

3. OVERVIEW

Vector is an emotionally expressive animatronic robot that we all love.

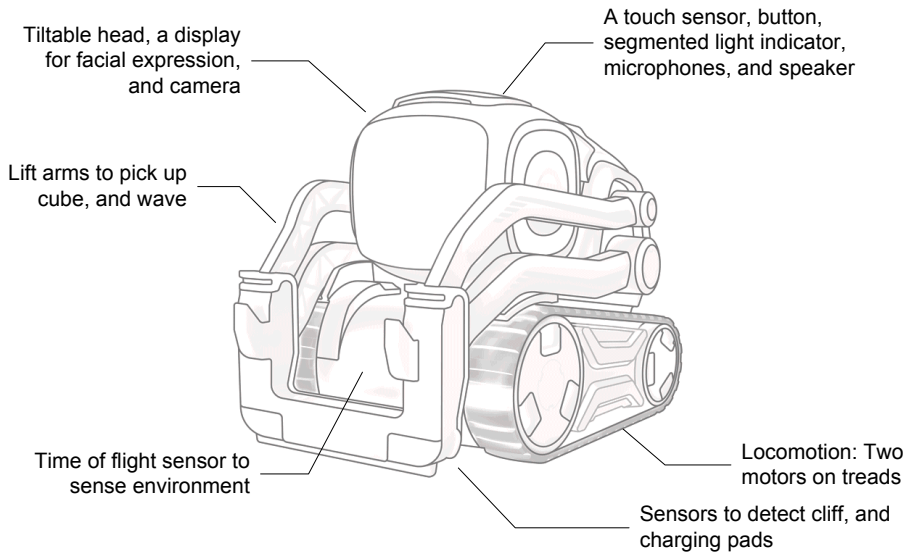

Figure 1: *Vector's main features*

Although cute, small, and affordable, Vector's design is structured like many other robots.

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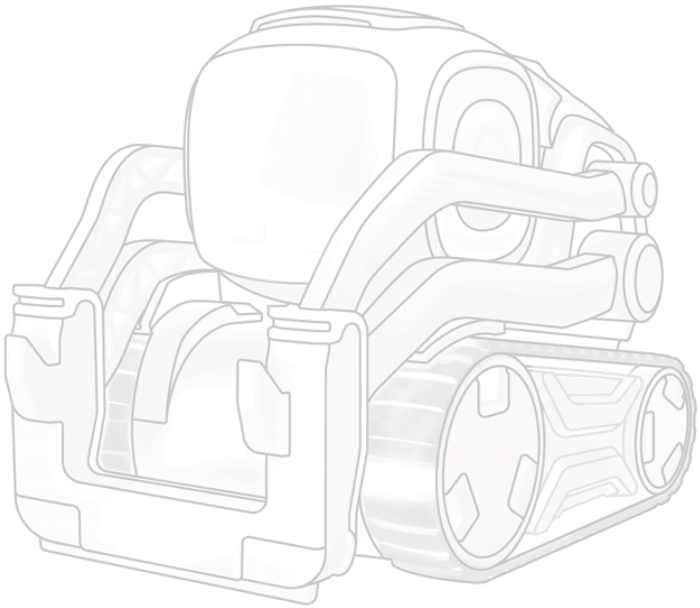
PART I

Electronics Design

This part provides an overview of the design of the electronics in Vector and his accessories

- VECTOR'S ELECTRICAL DESIGN. A detailed look at the electrical design of Vector.
- ACCESSORY ELECTRICAL DESIGN. A look at the electrical design of Vectors accessories.



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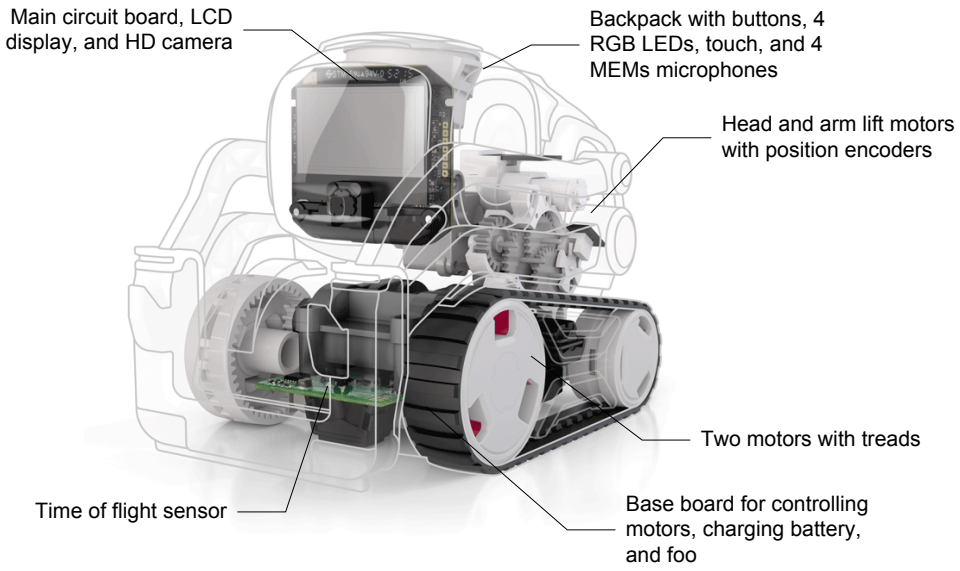
CHAPTER 2

Electronics design description

This chapter describes the electronic design of the Anki Vector:

- Main outline
- Overview
- Detailed design
- Power characteristics
- Connectors & Pin Maps

4. DESIGN OVERVIEW



CHAPTER 4

Accessory Electronics design description

This chapter describes the electronic design of the Anki Vector accessories:

- The charging station
- The companion cube

5. CHARGING STATION

The charging station is intended to provide energy to the Vector, allowing it to recharge. The charging station has a USB cable that plugs into an outlet adapter or battery. The adapter or battery supplies power to the charging station. The base of the station has two terminals to supply +5V (from the power adapter) to Vector, allowing him to recharge.

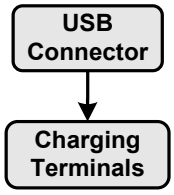
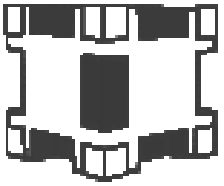


Figure 2: *Charging station block diagram*

The charging station has an optical marker used by Vector to identify the charging station and its pose (see chapter TBD).

6. CUBE

This section describes the companion cube's electronics. The companion cube is a small toy for Vector play with. He can fetch it, roll it, and use it to pop-wheelies. Each face of the cube has a unique optical marker used by Vector to identify the cube and its pose (see chapter TBD).



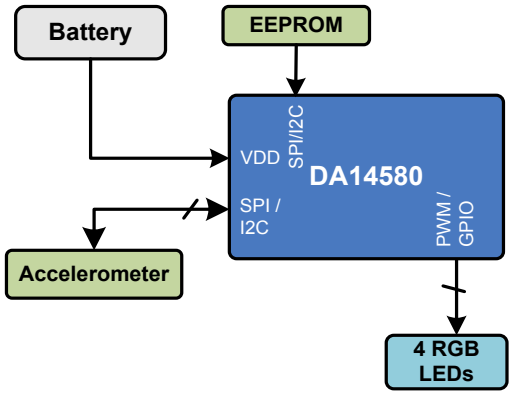


Figure 3: *Block diagram of the Cube's electronics*

The Cube's electronic design includes the following elements:

Element	Description
accelerometer	Used to detect movement and taps of the cube.
battery	The cube is powered by a 1.5 volt N / E90 / LR1 battery cell.[1]
crystal	The crystal provides the accurate frequency reference used by the Bluetooth LE radio.
Dialog DA14580	This is the Bluetooth LE module (transmitter/receiver, as well as microcontroller and protocol implementation).
EEPROM	The EEPROM holds the updatable application firmware.
RGB LEDs	There are 4 RGB LEDs. They can flash and blink. Unlike the backpack LEDs, two LEDs can have independent colors.

Table 1: *The Cube's electronic design elements*

The communication protocol is given appendix C.

6.1. OVER THE AIR FIELD UPDATES

The DA14580 has a minimal ROM bootloader that initializes hardware, moves a secondary bootloader from "One Time Programmable" ROM (OTP) into SRAM, before passing control to it. The firmware is executed from SRAM to reduce power consumption. The secondary bootloader loads the application firmware from I2C or SPI EEPROM or flash to SRAM and pass control to it.

If the application passes control back to the bootloader – or there isn't a valid application in EEPROM –a new application can be downloaded. The bootloader uses a different set of services and characteristics to support the bootloading process.

6.2. DATASHEETS

Dialog, *SmartBond™ DA14580 and DA14583*
https://www.dialog-semiconductor.com/products/connectivity/bluetooth-low-energy/smartbond-da14580-and-da14583

Dialog, *DA14580 Low Power Bluetooth Smart SoC, v3.1, 2015 Jan 29*

[1] The size is similar to the A23 battery, which will damage the cubes electronics.

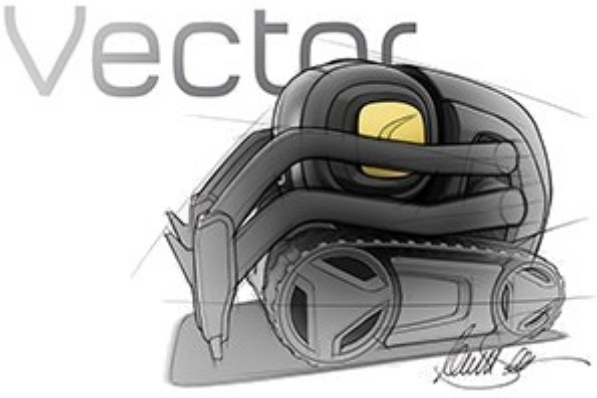
Dialog, *UM-B-012 User manual DA14580/581/583 Creation of a secondary bootloader*, CFR0012-00 Rev 2, 2016 Aug 24
Dialog, *Application note: DA1458x using SUOTA,* AN-B-10, Rev 1, 2016-Dec-2
https://www.dialog-semiconductor.com/sites/default/files/an-b-010_da14580_using_suota_0.pdf

PART II

Basic Operation

This part provides an overview of the design of the electronics in Vector and his accessories

- THE MAIN SOFTWARE MODULES. A detailed look at Vectors overall software architecture.
- THE BOOT. A look at the boot process.
- POWER MANAGEMENT
- SOUND.
- IMAGE PROCESSING & VISION.
- COMMUNICATION. A look at the communication stack in Vector.
- BLUETOOTH LE. The Bluetooth LE protocol that Vector responds to.
- CLOUD. A look at how Vector syncs with the cloud
- UPDATING. A look at how Vector updates itself



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CHAPTER 7

Bluetooth LE Communication Protocol

This chapter is describes Vector's Bluetooth LE communication protocol.

- The kinds of activities that can be done thru communication channels
- The interaction sequences
- The communication protocol stack, including encryption, fragmentation and reassembly.

Note: communication with the Cube is simple reading and writing a characteristic, and covered in Appendix C.

7. COMMUNICATION PROTOCOL OVERVIEW

Communication with Vector, once established, is structure as a request-response protocol. The request and responses are referred to as "C-Like Abstract Data structures" (CLAD) which are fields and values in a defined format, and interpretation. Several of these messages are used to maintain the link, setting up an encryption over the channel.

The application layer messages may be arbitrarily large. To support Bluetooth LE 4.1 (the version in Vector, and many mobile devices) the CLAD message must be broken up into small chunks to be sent, and then reassembled on receipt.

Combined with application-level encryption, the communication stack looks like:

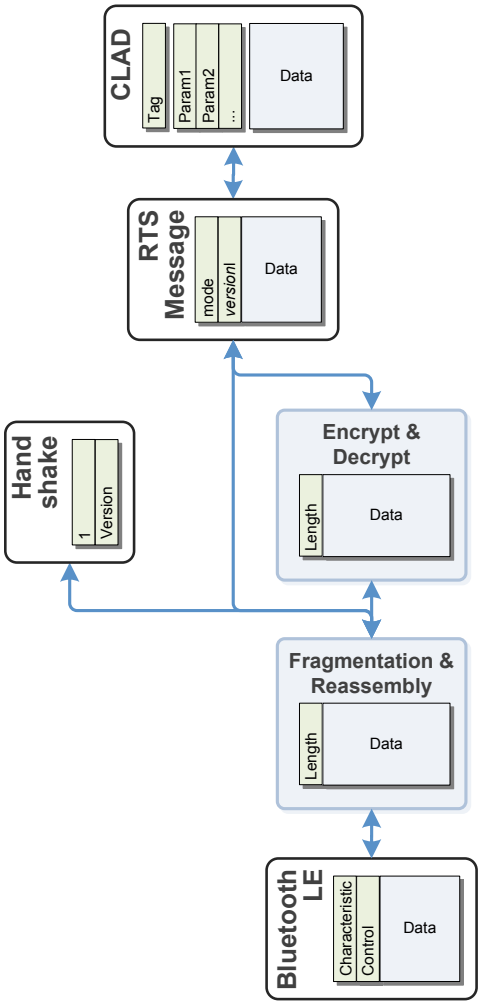

Figure 4: *Overview of encryption and fragmentation stack*

THE BLUETOOTH LE is the link/transport media. It handles the delivery, and low-level error detection of exchanging message frames. The frames are fragments of the overall message. The GUID's for the services and characteristics can be found in Appendix C.

THE FRAGMENTATION & REASSEMBLY is responsible for breaking up a message into multiple frames, and reassembling them into a message.

THE ENCRYPTION & DECRYPTION LAYER is used to encrypt and decrypt the messages, after the communication channel has been set up.

THE RTS is extra framing information that identifies the kind of CLAD message, and the version of its format. The format changed with version, so this version code is embedded at this layer.

THE C-LIKE ABSTRACT DATA (CLAD) is the layer that decodes the messages into values for fields, and interprets them,

7.1. SETTING UP THE COMMUNICATION CHANNEL

It sometimes helps to start with the over all process. This section will walk thru the process, referring to later sections where detailed information resides.

If you use "first time" – or wish to re-pair with him – put him on the charger, and press the backpack button twice quickly. He'll display a screen indicating he is getting ready to pair.

If you have already paired the application with Vector, the encryption keys can be reused.

1. The application opens Bluetooth LE connection (retrieving the service and characteristics handles), and subscribes to the "read" characteristic (see Appendix C for the UUID).
2. Vector sends *handshake* message; which the application receives. The handshake message structure is given below. The handshake message includes the version of the protocol supported.

***Table 2:** Parameters for Handshake message*

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*type*	?
1	4	uint32_t	*version*	The version of the protocol/messages to employ

3. The application sends the handshake back
4. Then the Vector will send a *connection request,* consisting of the public key to use for the session. The application's response depends on whether this is a first time pairing, or a reuse.
    a. First time pairing requires that Vector have already been placed into pairing mode prior to connecting to Vector. The application keys should be created (see section *7.3.1 First time pairing* above).
    b. Reconnection can reuse the public and secret keys, and the encryption and decryption keys from a prior pairing
5. The application should then send the publicKey in the response
6. If this is a first time pairing, Vector will display a *pin code*. This is used to create the public and secret keys, and the encryption and decryption keys (see section *7.3.1 First time pairing* above). These can be saved for use in future reconnection.
7. Vector will send a *nonce* message. After the application has sent its response, the channel will now be encrypted.
8. Vector will send a *challenge* message. The application should increment the passed value and send it back as a challenge message.
9. Vector will send a *challenge success* message.
10. The application can now send other commands

If the user puts Vector on the charger, and double clicks the backpack button, Vector will usually send a *disconnect* request.

7.2. FRAGMENTATION AND REASSEMBLY

An individual frame sent over Bluetooth LE is limited to 20 bytes. (This preserves compatibility with Bluetooth LE 4.1) A frame looks like:

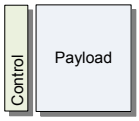

Figure 5: *The format of a frame*

The control byte is used to tell the receiver how to *reassemble* the message using this frame.

- If the MSB bit (bit 7) is set, this is the start of a new message. The previous message should be discarded.
- If the 2nd MSB (bit 6) is set, this is the end of the message; there are no more frames.
- The 6 LSB bits (bits 0..5) are the number of payload bytes in the frame to use.

The receiver would append the payload onto the end of the message buffer. If there are no more frames to be received it will pass the buffer (and size count) on to the next stage. If encryption has been set up, the message buffer will be decrypted and then passed to the RTS and CLAD. If encryption has not been set up, it is passed directly to the RTS & CLAD.

Fragmenting reverses the process:

1. Set the MSB bit of the control byte, since this is the start of a message.
2. Copy up to 19 bytes to the payload.
3. Set the number of bytes in the 6 LSB bits of the control byte
4. If there are no more bytes remaining, set the 2nd MSB it of the control byte.
5. Send the frame to Vector
6. If there are byte remaining, repeat from step 2.

7.3. ENCRYPTION SUPPORT

For the security layer, you will need the following

```
uint8_t Vectors_publicKey[32];
uint8_t publicKey [crypto_kx_PUBLICKEYBYTES];
uint8_t secretKey [crypto_kx_SECRETKEYBYTES];
uint8_t encryptionKey[crypto_kx_SESSIONKEYBYTES];
uint8_t decryptionKey[crypto_kx_SESSIONKEYBYTES];
uint8_t encryptionNonce[24];
uint8_t decryptionNonce[24];
uint8_t pinCode[16];
```

The variables mean:

Table 3: *The encryption variables*

Variable	Description
decryptionKey	The key used to decrypt each message from to Vector.
decryptionNonce	An extra bit that is added to each message. The initial nonce's to use are provided by Vector.
encryptionKey	The key used to encrypt each message sent to Vector.
encryptionNonce	An extra bit that is added to each message as it is encrypted. The initial nonce's to use are provided by Vector.
pinCode	6 digits that are displayed by Vector during an initial pairing.
Vectors_publicKey	The public key provided by Vector, used to create the encryption and decryption keys.

There are two different paths to setting up the encryption keys:

- First time pairing, and
- Reconnection

7.3.1 First time pairing

First time pairing requires that Vector be placed into pairing mode prior to the start of communication. This is done by placing Vector on the charger, and quickly double clicking the backpack button.

The application should generate its own internal *public* and *secret keys* at start.

```
crypto_kx_keypair(publicKey, secretKey);
```

The application will send a *connection response* with first-time-pairing set, and the public key. After Vector receives the connection response, he will display the *pin code*. (See the steps in the next section for when this will occur.)

The session *encryption* and *decryption keys* can then created:

```
crypto_kx_client_session_keys(decryptionKey, encryptionKey, publicKey, secretKey,
      Vector_publicKey);
size_t pin_length = strlen(pin);

crypto_generichash(encryptionKey, sizeof(encryptionKey), encryptionKey,
      sizeof(encryptionKey), pin, pin_length);
crypto_generichash(decryptionKey, sizeof(decryptionKey), decryptionKey,
      sizeof(decryptionKey), pin, pin_length);
```

7.3.2 Reconnecting

Reconnecting can reused the public and secret keys, and the encryption and decryption keys. It is not known how long these persist on Vector. {Next pairing? Next reboot? Indefinitely?}

7.3.3 Encrypting and decryption messages

Vector will send a *nonce* message with the *encryption* and *decryption nonces* to employ in encrypting and decrypting message.

Each received enciphered message can be decrypted from cipher text (cipher, and cipherLen) to the message buffer (message and messageLen) for further processing:

```
crypto_aead_xchacha20poly1305_ietf_decrypt(message, &messageLen, NULL, cipher,
      cipherLen,  NULL, 0L, decryptionNonce, decryptionKey);
sodium_increment(decryptionNonce, sizeof decryptionNonce);
```

Note: the decryptionNonce is incremented each time a message is decrypted.

Each message to be sent can be encrypted from message buffer (message and messageLen) into cipher text (cipher, and cipherLen) that can be fragmented and sent:

```
crypto_aead_xchacha20poly1305_ietf_encrypt(cipher, &cipherLen, message, messageLen,
      NULL, 0L, NULL, encryptionNonce, encryptionKey);
sodium_increment(encryptionNonce, sizeof encryptionNonce);
```

Note: the encryptionNonce is incremented each time a message is encrypted.

7.4. THE RTS LAYER

There is an extra, pragmatic layer before the messages can be interpreted by the application. The message has two to three bytes at the header:

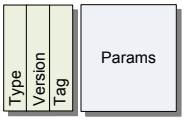

Figure 6: *The format of an RTS frame*

- The type byte is either 1 or 4. If it is 1 the version of the message format is 1.
- If type byte is 4, the version is held in the next byte. (If the type is 1, there is no version byte).
- The next byte is the tag – the value used to interpret the message.

The tag, parameter body, and version are passed to the CLAD layer for interpretation. This is described in the next section.

8. MESSAGE FORMATS

This section describes the format and interpretation of the CLAD messages that go between the App and Vector. It describes the fields and how they are encoded, etc. Fields that do not have a fixed location, have no value for their offset. Some fields are only present in later versions of the protocol. They are marked with the version that they are present.

Except where otherwise stated:

- Requests are from the mobile application to Vector, and responses are Vector to the application
- All values in little endian order

Table 4: *Summary of the commands*

	Request	Response	Min Version
Application connection id	$1F_{16}$	20_{16}	4
Cancel pairing	10_{16}		0
Challenge	04_{16}	04_{16}	0
Challenge success	05_{16}		0
Connect	01_{16}	02_{16}	0
Cloud session	$1D_{16}$	$1E_{16}$	3
Disconnect	11_{16}		0
File download	26_{16}		2
Log	18_{16}	19_{16}	2
Nonce	03_{16}	12_{16}	
OTA cancel	17_{16}		2
OTA update	$0E_{16}$	$0F_{16}$	0
SDK proxy	22_{16}	23_{16}	5
Response	21_{16}		4
SSH	15_{16}	16_{16}	0
Status	$0A_{16}$	$0B_{16}$	0
WiFi access point	13_{16}	14_{16}	0
WiFi connect	06_{16}	07_{16}	0
WiFi forget	$1B_{16}$	$1C_{16}$	3
WiFi IP	08_{16}	09_{16}	0
WiFi scan	$0C_{16}$	$0D_{16}$	0

8.1. APPLICATION CONNECTION ID

?

8.1.1 Request

The parameters of the request body are:

Offset	Size	Type	Parameter	Description
0	2	uint16_t	*name length*	The length of the application connection id; may be 0
2	*varies*	uint8_t[name length]	*name*	The application connection id

Table 5: *Parameters for Application Connection Id request*

8.1.2 Response

There is no response.

8.2. CANCEL PAIRING

Speculation: this is sent by the application to cancel the pairing process

8.2.1 Request

The command has no parameters.

8.2.2 Response

There is no response.

8.3. CHALLENGE

This is sent by Vector if he liked the response to a nonce message.

8.3.1 Request

The parameters of the request body are:

Offset	Size	Type	Parameter	Description
0	4	uint8_t	*value*	The challenge value

Table 6: *Parameters for challenge request*

The application, when it receives this message, should increment the value and send the response (a challenge message).

8.3.2 Response

The parameters of the response body are:

Offset	Size	Type	Parameter	Description
0	4	uint8_t	*value*	The challenge value; this is 1 + the value that was received.

Table 7: *Parameters for challenge response*

If Vector accepts the response, he will send a *challenge success.*

8.4. CHALLENGE SUCCESS

This is sent by Vector if the challenge response was accepted.

8.4.1 Request

The command has no parameters.

8.4.2 Response

There is no response.

8.5. CLOUD SESSION

This command is used to request a cloud session [TBD]

8.5.1 Command

The parameters of the request body are:

Offset	Size	Type	Parameter	Description
0	2	uint16_t	*token length*	The number of bytes in the token; may be 0
2	varies	uint8_t	*token*	The session token
	1	uint8_t	*client name length*	The number of bytes in the client name string; may be 0 version >= 5
	varies	uint8_t[]	*client name*	The client name [?] string version >= 5
	1	uint8_t	*application id length*	The number of bytes in the application id string; may be 0 version >= 5
	varies	uint8_t[]	*application id*	The application id version >= 5

Table 8: *Parameters for Cloud Session request*

8.5.2 Response result

The parameters for the connection response message:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*success*	0 if failed, otherwise successful
1	1	uint8_t	*status*	See *Table 10: Cloud status enumeration*
2	1	uint16_t	*token length*	The number of bytes in the client token GUID; may be 0
	varies	uint8_t[]	*token*	The client token GUID

Table 9: *Parameters for Cloud Session Response*

The cloud status types are:

Index	Meaning
0	unknown error
1	connection error
2	wrong account
3	invalid session token
4	authorized as primary
5	authorized as secondary
6	reauthorization

Table 10: *Cloud status enumeration*

8.6. CONNECT

The connect request *comes from Vector* at the start of a connection. The response is from the application.

8.6.1 Request

The parameters of the request body are:

Offset	Size	Type	Parameter	Description
0	32	uint8_t[32]	*publicKey*	The public key for the connection

***Table 11:** Parameters for Connection request*

The application, when it receives this message, should use the public key for the session, and send a response back.

8.6.2 Response

The parameters for the connection response message:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*connectionType*	See *Table 13: Connection types enumeration*
1	32	uint8_t[32]	*publicKey*	The public key to use for the connection

***Table 12:** Parameters for Connection Response*

The connection types are:

Index	Meaning
0	first time pairing (requests pin code to be displayed)
1	reconnection

***Table 13:** Connection types enumeration*

The application sends the response, with its publicKey (see section *7.2 Fragmentation and* reassembly

An individual frame sent over Bluetooth LE is limited to 20 bytes. (This preserves compatibility with Bluetooth LE 4.1) A frame looks like:

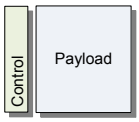

***Figure 5:** The format of a frame*

The control byte is used to tell the receiver how to *reassemble* the message using this frame.

- If the MSB bit (bit 7) is set, this is the start of a new message. The previous message should be discarded.
- If the 2nd MSB (bit 6) is set, this is the end of the message; there are no more frames.
- The 6 LSB bits (bits 0..5) are the number of payload bytes in the frame to use.

The receiver would append the payload onto the end of the message buffer. If there are no more frames to be received it will pass the buffer (and size count) on to the next stage. If encryption has been set up, the message buffer will be decrypted and then passed to the RTS and CLAD. If encryption has not been set up, it is passed directly to the RTS & CLAD.

Fragmenting reverses the process:

7. Set the MSB bit of the control byte, since this is the start of a message.
8. Copy up to 19 bytes to the payload.
9. Set the number of bytes in the 6 LSB bits of the control byte
10. If there are no more bytes remaining, set the 2nd MSB it of the control byte.
11. Send the frame to Vector
12. If there are byte remaining, repeat from step 2.

Encryption support). A “first time pairing” connection type will cause Vector to display a pin code on the screen

If a first time pairing response is sent:

- If Vector is not in pairing mode – was not put on his charger and the backpack button pressed twice, quickly – Vector will respond. Attempting to enter pairing mode now will cause Vector to send a *disconnect* request.
- If Vector is in pairing mode, Vector will display a pin code on the screen, and send a nonce message, triggering the next steps of the conversation.

If a reconnection is sent, the application would employ the public and secret keys, and the encryption and decryption keys from a prior pairing.

8.7. DISCONNECT

This may be sent by Vector if there is an error, and it is ending communication. For instance, if Vector enters pairing mode, it will send a disconnect.

The application may send this to request Vector to close the connection.

8.7.1 Request

The command has no parameters.

8.7.2 Response

There is no response.

8.8. FILE DOWNLOAD

This command is used to pass chunks of a file to Vector. Files are broken up into chunks, and sent.

8.8.1 Request

The parameters of the request body are:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*status*	
1	4	uint32_t	*file id*	
5	4	uint32_t	*packet number*	The chunk within the download
9	4	uint32_t	*packet total*	The total number of packets to be sent for this file download
13	2	uint12_t	*length*	The number of bytes to follow (can be 0)
	varies	uint8_t[length]	*bytes*	The bytes of this file chunk

Table 14: *Parameters for File Download request*

8.8.2 Response

There is no response [?TBD?]

8.9. LOG

This command is used to request the Vector TBD logging

8.9.1 Request

The parameters of the request body are:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*mode*	
1	2	uint16_t	*num filters*	The number of filters in the array
3	varies	filter[num filters]	*filters*	The filter names

Table 15: *Parameters for Log request*

Each filter entry has the following structure:

Offset	Size	Type	Parameter	Description
0	2	uint16_t	*filter length*	The length of the filter name; may be 0
2	*varies*	uint8_t[filter length]	*filter name*	The filter name

Table 16: *Log filter*

8.9.2 Response

The parameters for the response message:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*exit code*	
1	4	uint32_t	*file id*	

Table 17: *Parameters for Log Response*

8.10. NONCE

A nonce is sent by Vector after he has accepted your key, and the application sends a response

8.10.1 Request

The parameters for the nonce request message:

Offset	Size	Type	Parameter	Description
0	24	uint8_t[24]	*toVectorNonce*	The nonce to use for sending stuff to Vector
24	24	uint8_t[24]	*toAppNonce*	The nonce for receiving stuff from Vector

Table 18: *Parameters for Nonce request*

8.10.2 Response

After receiving a nonce, if the application is in first-time pairing the application should send a response, with a value of 3.

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*connection tag*	This is always 3

After the response has been sent, the channel will now be encrypted. If vector likes the response, he will send a challenge message.

8.11. OTA UPDATE

This command is used to request the Vector download firmware from a given server

8.11.1 Request

The parameters of the request body are:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*length*	The length of the URL; may be 0
1	*varies*	uint8_t[length]	*URL*	The URL string

Table 19: *Parameters for OTA request*

8.11.2 Response

The parameters for the response message:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*status*	See *Table 21: OTA status enumeration*
1	8	uint64_t	*current*	The number of bytes downloaded
9	8	uint64_t	*expected*	The number of bytes expected to be downloaded

Table 20: *Parameters for OTA Response*

The OTA status are:

Index	Meaning
0	idle
1	unknown
2	in progress
3	complete
4	rebooting
5	error

Table 21: *OTA status enumeration*

8.12. RESPONSE

It is not known why this message will be sent.

Table 22: Parameters for Response

Offset	Size	Type	Parameter	Description
0	1	uint16_t	*code*	0 if not cloud authorized, otherwise authorized
1	1	uint8_t	*length*	
	varies	uint8_t [length]	*bytes*	

8.13. SDK PROXY

This command is used to pass the gRPC/protobufs messages to Vector over Bluetooth LE. It effectively wraps a HTTP request/response.

8.13.1 Request

The parameters of the request body are:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*GUID length*	The number of bytes in the GUID string; may be 0
2	*varies*	uint8_t[GUID length]	*GUID*	The GUID string
	1	uint8_t	*msg length*	The number of bytes in the message id string
	varies	uint8_t[msg id length]	*msg id*	The message id string
	1	uint8_t	*path length*	The number of bytes in the URL path string
	varies	uint8_t[path length]	*path*	The URL path string
	2	uint16_t	*JSON length*	The length of the JSON
	varies	uint8_t[JSON length]	*JSON*	The JSON (string)

Table 23: *Parameters for the SDK proxy request*

8.13.2 Response

The parameters for the response message:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*msg id length*	The number of bytes in the message id string; may be 0
2	*varies*	uint8_t[msg id length]	*msg id*	The message id string
	2	uint16_t	*status code*	The HTTP-style status code that the SDK may return.
	1	uint8_t	*type length*	The number of bytes in the response type string
	varies	uint8_t[type length]	*type*	The response type string
	2	uint16_t	*body length*	The length of the response body
	varies	uint8_t[body length]	*body*	The response body (string)

Table 24: *Parameters for the SDK proxy Response*

8.14. SSH

This command is used to request the Vector allow SSH. It is not known which version of the Vector support SSH, or whether it is enabled in the release.

8.14.1 Request

The parameters for the request message:

Table 25: Parameters for SSH request

Offset	Size	Type	Parameter	Description
0	2	uint16_t	*num keys*	The number of SSH authorization keys; may be 0
2	*varies*	keys[num keys]	*keys*	The array of authorization key strings (see below).

Each authorization key has the following structure:

Table 26: SSH authorization key

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*key length*	The length of the key; may be 0
1	*varies*	uint8_t[key length]	*key*	The SSH authorization key

8.14.2 Response

The response has no parameters

8.15. STATUS

This command is used to request the Vector act basic info.

8.15.1 Request

The request has no parameters

8.15.2 Response

The parameters for the response message:

***Table 27:** Parameters for Status Response*

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*SSID length*	The number of bytes in the SSID string; may be 0
2	*varies*	uint8_t[SSID length]	*SSID*	The WiFi SSID (hex string)
	1	uint8_t	*WiFi state*	See *Table 28: WiFi state enumeration*
	1	uint8_t	*access point*	0 not acting as an access point, otherwise acting as an access point
	1	uint8_t	*Bluetooth LE state*	
	1	uint8_t	*Battery state*	
	1	uint8_t	*version length*	The number of bytes in the version string; may be 0 version >= 2
	varies	uint8_t [version length]	*version*	The version string; version >= 2
	1	uint8_t	*ESN length*	The number of bytes in the ESN string; may be 0 version >= 4
	varies	uint8_t[ESN length]	*ESN*	The *electronic serial number* string; version >= 4
	1	uint8_t	*OTA in progress*	0 over the air update not in progress, otherwise in process of over the air update; version >= 2
	1	uint8_t	*has owner*	0 does not have owner, otherwise has owner; version >= 3
	1	uint8_t	*cloud authorized*	0 is not cloud authorized, otherwise is cloud authorized; version >= 5

Note: a *hex string* is a series of bytes with values 0-15. Every pair of bytes must be converted to a single byte to get the characters. Even bytes are the high nibble, odd bytes are the low nibble.

The WiFi states are:

***Table 28:** WiFi state enumeration*

Index	Meaning
0	Unknown
1	Online
2	Connected
3	Disconnected

8.16. WIFI ACCESS POINT

This command is used to request that the Vector act as a WiFi access point.

8.16.1 Request

The parameters of the request body are:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*enable*	0 to disable the WiFi access point, 1 to enable it

Table 29: *Parameters for WiFi Access Point request*

8.16.2 Response

The parameters for the response message:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*enabled*	0 if the WiFi access point is disabled, otherwise enabled
1	1	uint8_t	*SSID length*	The number of bytes in the SSID string; may be 0
2	*varies*	uint8_t[SSID length]	*SSID*	The WiFi SSID (hex string)
	1	uint8_t	*password length*	The number of bytes in the password string; may be 0
	varies	uint8_t [password length]	*password*	The WiFi password

Table 30: *Parameters for WiFi Access Point Response*

8.17. WIFI CONNECT

This command is used to request the Vectors connect to a given WiFi SSID. Vector will retain this WiFi for future use.

8.17.1 Request

The parameters for the request message:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*SSID length*	The number of bytes in the SSID string; may be 0
1	*varies*	uint8_t[SSID length]	*SSID*	The WiFi SSID (hex string)
	1	uint8_t	*password length*	The number of bytes in the password string; may be 0
	varies	uint8_t [password length]	*password*	The WiFi password
	1	uint8_t	*timeout*	How long to given the connect attempt to succeed.
	1	uint8_t	*auth type*	The type of authentication to employ; see *Table 32: WiFi authentication types enumeration*
	1	uint8_t	*hidden*	0 the access point is not hidden; 1 it is hidden

***Table 31:** Parameters for WiFi Connect request*

The WiFi authentication types are:

Index	Meaning
0	None, open
1	WEP
2	WEP shared
3	IEEE8021X
4	WPA PSK
5	WPA2 PSK
6	WPA2 EAP

***Table 32:** WiFi authentication types enumeration*

8.17.2 Response

The parameters for the response message:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*SSID length*	The length of the SSID that was deleted; may be 0
1	*varies*	uint8_t[SSID length]	*SSID*	The SSID (hex string) that was deleted
	1	uint8_t	*WiFi state*	See *Table 28: WiFi state enumeration*
	1	uint8_t	*connect result*	version >= 3

***Table 33:** Parameters for WiFi Connect command*

8.18. WIFI FORGET

This command is used to request the Vectors forget a WiFi SSID.

8.18.1 Request

The parameters for the request message:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*delete all*	0 if Vector should delete only one SSID; otherwise Vector should delete all SSIDs
1	1	uint8_t	*SSID length*	The length of the SSID that to be deleted; may be 0
2	*varies*	uint8_t[SSID length]	*SSID*	The SSID (hex string) to be deleted

Table 34: *Parameters for WiFi Forget request*

8.18.2 Response

The parameters for the response message:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*did delete all*	0 if only one; otherwise Vector deleted all SSIDs
1	1	uint8_t	*SSID length*	The length of the SSID that was deleted; may be 0
2	*varies*	uint8_t[SSID length]	*SSID*	The SSID (hex string) that was deleted

Table 35: *Parameters for WiFi Forget response*

8.19. WIFI IP ADDRESS

This command is used to request the Vectors WiFi IP address.

8.19.1 Request

The request has no parameters

8.19.2 Response

The parameters for the response message:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*has IPv4*	0 if Vector doesn't have an IPv4 address; other it does
1	1	uint8_t	*has IPv6*	0 if Vector doesn't have an IPv6 address; other it does
2	4	uint8_t[4]	*IPv4 address*	Vector's IPv4 address
6	32	uint8_t[16]	*IPv6 address*	Vector's IPv6 address

Table 36: *Parameters for WiFi IP Address response*

8.20. WIFI SCAN

This command is used to request the Vectors scan for WiFi access points.

8.20.1 Request

The command has no parameters.

8.20.2 Response

The parameters for the response message:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*status code*	
1	1	uint8_t	*num entries*	The number of access points in the array below
2	*varies*	AP[num entries]	*access points*	The array of access points

Table 37: *Parameters for WiFi scan response*

Each access point has the following structure:

Offset	Size	Type	Parameter	Description
0	1	uint8_t	*auth type*	The type of authentication to employ; see *Table 32: WiFi authentication types enumeration*
1	1	uint8_t	*signal strength*	The number of bars, 0..4
2	1	uint8_t	*SSID length*	The length of the SSID string
3	*varies*	uint8_t[SSID length]	*SSID*	The SSID (hex string)
	1	uint8_t	*hidden*	0 not hidden, 1 hidden; version >= 2
	1	uint8_t	*provisioned*	0 not provisioned, 1 provisioned; version>= 3

Table 38: *Parameters access point structure*

CHAPTER 8

The Cloud Services

This chapter is about the cloud

- The user's account settings and entitlements
- The robot's settings (user preferences)
- The robot's lifetime stats
- The crash uploader
- The firmware update process
- How to extract official program files

9. THE JDOC SERVER

9.1. THE USER ACCOUNT SETTINGS

Sent to the jdoc server

Schema: TBD

9.2. ROBOT SETTINGS

Sent to the jdoc server

These are an ad hoc set of locale preferences. The following are sent to the jdoc server by the mobile application, and retrieved by the robot:

***Table 39:** The robot settings.*

Key	units	Description & Notes
button_wakeword	?	
clock_24_hour	boolean	
default_location		
dist_is_metric		
eye_color		The color used for the eyes
locale		American English, UK English, Australian English, German, French, Japanese, etc.
master_volume		
temp_is_fahrenheit		
time_zone		

9.3. USER ENTITLEMENTS

Sent to the jdoc server

Schema: TBD

Appear to be the private and public keys

9.4. ROBOT LIFETIME STATS

Sent to the jdoc server

The following are held in the server, updated by the robot (I don't know if the robot has a local copy), and retrievable by the application. A JSON hash of the following:

Table 40: *The robot lifetime stats schema*

Key	units	Description & Notes
Alive.seconds	seconds	Vectors age, since he was given preferences (a factory reset restarts this)
Stim.CumlPosDelta		Cumulative stimulation of some kind
BStat.AnimationPlayed	count	The number of animations played
BStat.BehaviorActivated	count	
BStat.AttemptedFistBump	count	The number of fist bumps (attempted)
BStat.FistBumpSuccess	count	
BStat.PettingBlissIncrease		
BStat.PettingReachedMaxBliss		
BStat.ReactedToCliff	count	
BStat.ReactedToEyeContact	count	
BStat.ReactedToMotion	count	
BStat.ReactedToSound	count	
BStat.ReactedToTriggerWord	count	
Feature.AI.DanceToTheBeat		
Feature.AI.Exploring		
Feature.AI.FistBump		
Feature.AI.GoHome		
Feature.AI.InTheAir		
Feature.AI.InteractWithFaces	count	The number of times recognized / interacted with faces
Feature.AI.Keepaway		
Feature.AI.ListeningForBeats		
Feature.AI.LowBattery		
Feature.AI.Observing		
Feature.AI.ObservingOnCharger		
Feature.AI.Onboarding		
Feature.AI.Sleeping		

Feature.AI.Petting		
Feature.AI.ReactToCliff		
Feature.AI.StuckOnEdge		
Feature.AI.UnmatchedVoiceIntent		
Feature.Voice.VC_Greeting		
FeatureType.Autonomous		
FeatureType.Failure		
FeatureType.Sleep		
FeatureType.Social		
FeatureType.Play		
FeatureType.Utility1		
Pet.ms	ms	The number of milliseconds petted?
Odom.LWheel		The left wheel odometer
'Odom.Rwheel		The right wheel odometer
Odom.Body		

References & Resources

Note: most references appear in the margins, significant references will appear at the end of their respective chapter.

10. CREDITS

Credit and thanks to Anki, C0RE, MelanieT for access to the partition file-system, and decode keys; board shots. Fictiv for board shots. The board shots that help identify parts on the board and inter-connection on the board.

11. REFERENCE DOCUMENTATION AND RESOURCES

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Anki, Daniel Casner, Lee Crippen, Hanns Tappeiner, Anthony Armenta, Kevin Yoon, *Map Related Acoustic Filtering by a Mobile Robot,* Patent US 0212441 A1, 2019 Jul 11

Anki, Andrew Stein, *Decoding Machine-Readable Optical codes with Aesthetic Component*, Patent US 9,607,199 B2, 2017 Mar. 28

11.2. OTHER

FCC *ID 2AAIC00010 internal photos*
https://fccid.io/2AAIC00010

FCC *ID 2AAIC00011 internal photos*
https://fccid.io/2AAIC00011

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https://www.fictiv.com/blog/anki-vector-robot-teardown

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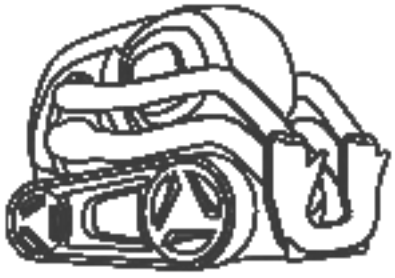
https://www.kinvert.com/anki-vector-customer-care-info-screen-ccis/

Appendices

- ABBREVIATIONS, ACRONYMS, & GLOSSARY. This appendix provides a gloss of terms, abbreviations, and acronyms.
- TOOL CHAIN. This appendix lists the tools known or suspected to have been used by Anki to create, and customize the Vector, and for the servers. Tools that can be used to analyze vector
- BLUETOOTH LE PROTOCOLS. This appendix provides information on the Bluetooth LE interfaces to the companion Cube, and to Anki Vector
- SERVERS. This appendix provides the servers that the Anki Vector and App contacts
- PHRASES. This appendix reproduces the phrases that the Vector keys off of.
- FEATURES. This appendix enumerates the Vector OS "features" that can be enabled and disabled.
- FILE SYSTEM. This appendix lists the key files that are baked into the system.
- CONFIGURATION. This appendix recaps the configuration values.
- BEHAVIOURS. This appendix provides a list of the behaviours that Vector has built in.
- ANIMATIONS. This appendix provides a list of the animations that Vector has built in.
- ACTIONS. This appendix provides a list of the actions that Vector has built in.



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APPENDIX A

Abbreviations, Acronyms, Glossary

Table 41: Common acronyms and abbreviations

Abbreviation / Acronym	Phrase
ADC	analog to digital converter
AG	animation group
AVS	Alexa Voice Service
BIN	binary file
CCIS	customer care information screen
CLAD	C-like abstract data structures
CRC	cyclic redundancy check
DAS	data analytics service ?
DFU	device firmware upgrade
EEPROM	electrical-erasable programmable read-only memory
ESD	electro-static discharge
ESN	electronic serial number
GPIO	general purpose IO
I2C	Inter-IC communication
IMU	inertial measurement unit
IR	infrared
JTAG	Joint Test Action Group
LCD	liquid crystal display
LED	light emitting diode
LUKS	linux unified key setup
MEMS	micro-electromechanical systems
MISO	Master-in, slave-out
MOSI	Master-out, slave-in
OLED	organic light-emitting diode display
OTA	over the air updates
RRT	rapidly-expanding random tree
SCLK	(I2C) serial clock

SDA	(I2C) serial data
SDK	software development kit
SPI	serial-peripheral interface
SSH	secure shell
SSID	service set identifier (the name of the Wifi network)
STM32	A microcontroller family from ST Microelectronics
SWD	single wire debug
TTS	text to speech
UART	universal asynchronous receiver/transmitter
USB	universal serial bus
UUID	universally unique identifier
vic	short Victor (Vector's working name)

Table 42: *Glossary of common terms and phrases*

Phrase	Description
A*	A path finding algorithm
attitude	orientation
bootloader	A piece of software used to load and launch the application firmware.
C-like abstract data structure	Anki's phrase for when information is packed into fields and values with a defined binary format, and interpretation.
capacitive touch	
characteristic (Bluetooth LE)	A key (or slot) that holds a value in the services key-value table. A characteristic is uniquely identified by its UUID.
control	motors and forces to move where and how it is told to. (smooth arcs)
D*-lite	A path-finding algorithm
flash	A type of persistent (non-volatile) storage media.
guidance	desired path
navigation	knowing where it is in the map
nonce	An initially random number, incremented after each use .
pose	position and orientation of an object relative to a coordinate system
power source	Where the electric energy comes from.
path planning	smooth arcs and line segments
rapidly-expanding random tree	A path-finding algorithm
service (Bluetooth LE)	A key-value table, grouped together for a common purrpose. A service is uniquely identified by its UUID.
universally unique identifier (UUID)	A 128bits number that is unique.

APPENDIX B

Tool chain

This appendix tries to capture the tools that Anki is known or suspected to have used for the Anki Vector and its cloud server.

Note: Several of these the licenses requiring Anki to post their versions of the GPL tools, and their modification, Anki never did. Qualcomm may have; as the license requirement only to those their customer, they may have provided the changes to them.

***Table 43:** Tools used by Anki*

Tool	Description
Acapela	Vector uses Acapela's text to speech synthesizer, and the Ben voice. https://www.acapela-group.com/
Advanced Linux Sound Architecture (alsa)	The audio system https://www.alsa-project.org
Amazon Alexa	A set of software tools that allows Vector to integrate Alexa voice commands, probably in the AMAZONLITE distribution https://developer.amazon.com/alexa-voice-service/sdk
Amazon Web services	used on the server https://aws.amazon.com/
android boot-loader	Vector uses the Android Boot-loader;
AudioKinetic Wwise[2]	Used to craft the sounds https://www.audiokinetic.com/products/wwise/
clang	A C/C++ compiler, part of the LLVM family https://clang.llvm.org
bluez5	Bluetooth LE support http://www.bluez.org/
busybox	The shell on the Anki Vector linux https://busybox.net
chromium update	?
civetweb	The embedded webserver that allows Mobile apps and the python SDK to communicate with Vector. https://github.com/civetweb/civetweb
connman	Connection manager for WiFi https://01.org/connman
GNU C Compiler (gcc)	GCC version 4.9.3 was used to compile the kernel
golang	on the server
Google RPC (gRPC)	A "remote procedure call" standard, that allows mobile apps and the python SDK

[2] https://blog.audiokinetic.com/interactive-audio-brings-cozmo-to-life/?hsFormKey=227ccf4a650a1cffd6562c16d655a0ef

	to communicate with Vector. https://grpc.io/docs/quickstart/cpp/
hdr-histogram	Unknown use https://github.com/HdrHistogram/HdrHistogram
libchromatix	Qualcomm camera support
libsodium	Cryptography library suitable for the small packet size in Bluetooth LE connections. Used to encrypt the mobile applications Bluetooth LE connection with Vector. https://github.com/jedisct1/libsodium
linux, yocto[3]	The family of linux distribution used for the Anki Vector (v3.18.66)
linux	on the server
linux unified key storage (LUKS)	
Maya	A character animation tool set, used to design the look and movements of Cozmo and Vector. The tool emitted the animation scripts.
mpg123	A MPEG audio decoder and player. This is needed by Alexa; other uses are unknown. https://www.mpg123.de/index.shtml
ogg vorbis	Audio codec https://xiph.org/vorbis
open CV	Used for the first-level image processing – to locate faces, hands, and possibly accessory symbols. https://opencv.org/
openssl	used to validate firmware update signature https://www.openssl.org
opkg	Package manager, from yocto https://git.yoctoproject.org/cgit/cgit.cgi/opkg/
Opus codec	Audio codec; may be used to encode speech sent to servers http://opus-codec.org/
perl	A programming language, on Victor https://www.perl.org
protobuf	Used to describe the format/encoding of data sent over gRPC to and from Vector. This is used by mobile and python SDK, as well as on the server. https://developers.google.com/protocol-buffers
Pryon	The recognition for the Alexa keyword at least the file system includes the same model as distributed in AMAZONLITE https://www.pryon.com/company/
python	A programming language and framework, used with desktop tools to communicate with Vector. Vector has python installed. Probably used on the server as well. https://www.python.org
Qualcomm TBD	Qualcomm's device drivers, and other kit appears to be used.
Segger ICD	A high-end ARM compatible in-circuit debugging probe. Rumoured to have been used by Anki engineers, probably with the STM32F030 https://www.segger.com/products/debug-probes/j-link/

[3] https://www.designnews.com/electronics-test/lessons-after-failure-anki-robotics/140103493460822

Sensory	Includes recognition for hey vector and Alexa wake word by Sensory, Inc. https://en.wikipedia.org/wiki/Sensory,_Inc.
SQLite	This is needed by Alexa; other uses are unknown https://www.sqlite.org/index.html
systemd	Used by Vector to launch the internal services https://www.freedesktop.org/software/systemd/
tensor flow lite (TFLite)	Probably used to recognize the object marker symbols, and maybe hands https://www.tensorflow.org/lite/microcontrollers/get_started

Other tools, useful for analyzing and patching Vector:

Table 44: *Tools that can be used to analyze and patch Vector*

Toool	**Description**
Segger ICD	An education version of the J-Link, suitable for the STM32F030, can be found on ebay for <$60 https://www.segger.com/products/debug-probes/j-link/
ST-Link (v3)	Suitable for extracting the STM32F030 and installing patched firmware; $35 https://www.st.com/en/development-tools/stlink-v3set.html
TI BLE sniffer	$50 http://www.ti.com/tool/CC2540EMK-USB https://www.ti.com/tool/PACKET-SNIFFER
Wireshark	To decode what is said to the servers https://support.citrix.com/article/CTX116557

APPENDIX C

Bluetooth LE Services & Characteristics

This Appendix describes the configuration of the Bluetooth LE services – and the data access they provide – for the accessory cube and for Vector.

12. CUBE SERVICES

times and other feature parameters:

Service	UUID[4]	Description & Notes
Device Info Service[5]	$180A_{16}$	Provides device and unit specific info – it's manufacturer, model number, hardware and firmware versions
Generic Access Profile[6]	1800_{16}	The device name, and preferred connection parameters
Generic Attribute Transport[7]	1801_{16}	Provides access to the services.
Cube's Service	C6F6C70F-D219-598B-FB4C-308E1F22F830$_{16}$	Service custom to the cube, reporting battery, accelerometer and date of manufacture

***Table 45:** The Bluetooth LE services*

Note: It appears that there isn't a battery service on the Cube. When in over-the-air update mode, there may be other services present (i.e. by a bootloader)

Element	Value
Device Name (Default)	"Vector Cube"
Firmware Revision	"v_5.0.4"
Manufacturer Name	"Anki"
Model Number	"Production"
Software Revision	"2.0.0"

***Table 46:** The Cube's Device info settings*

[4] All values are a little endian, per the Bluetooth 4.0 GATT specification
[5] http://developer.bluetooth.org/gatt/services/Pages/ServiceViewer.aspx?u=org.bluetooth.service.device_information.xml
[6] http://developer.bluetooth.org/gatt/services/Pages/ServiceViewer.aspx?u=org.bluetooth.service.generic_access.xml
[7] http://developer.bluetooth.org/gatt/services/Pages/ServiceViewer.aspx?u=org.bluetooth.service.generic_attribute.xml

12.1. CUBE'S ACCELEROMETER SERVICE

Values are little-endian, except where otherwise stated.

UUID	Access	Size	Notes
0EA75290-6759-A58D-7948-598C4E02D94A$_{16}$	*Write*	unknown	
450AA175-8D85-16A6-9148-D50E2EB7B79E$_{16}$	Read	The date and time of manufacture (?)	
		char[]	*A date and time string*
43EF14AF-5FB1-7B81-3647-2A9477824CAB$_{16}$	Read, Notify, Indicate	Reads the battery and acceleromter	
		uint16_t	*battery ADC value*
		uint16_t	*accelerometer X ADC value #1*
		uint16_t	*accelerometer Y ADC value #1*
		uint16_t	*accelerometer Z ADC value #1*
		uint16_t	*accelerometer X ADC value #2*
		uint16_t	*accelerometer Y ADC value #2*
		uint16_t	*accelerometer Z ADC value #2*
		uint16_t	*accelerometer X ADC value #3*
		uint16_t	*accelerometer Y ADC value #3*
		uint16_t	*accelerometer Z ADC value #3*
		uint16_t	
9590BA9C-5140-92B5-1844-5F9D681557A4$_{16}$	Write		Unknown

***Table 47:** Cube's accelerometer service characteristics*

Presumably some of these will cause the Cube to go into over the air update (OTAU) mode, allowing its firmware to be updated.

Others turn the RGB on to an RGB color, possibly duty cycle and pulsing duty cycle

13. VECTOR SERVICES SERVICE

times and other feature parameters:

Service	UUID[8]	Description & Notes
Generic Access Profile	1800_{16}	The device name, and preferred connection parameters
Generic Attribute Transport	1801_{16}	Provides access to the services.
Vectors Serial Service	$FEE3_{16}$	The service with which we can talk to Vector.

***Table 48:** Vector's Bluetooth LE services*

It appears that there isn't a battery service on the Vector.

Element	Value
Device Name (Default)	"Vector" followed by his serial number

***Table 49:** The Vector's Device info settings*

[8] All values are a little endian, per the Bluetooth 4.0 GATT specification

13.1. VECTORS SERIAL SERVICE

UUID	Access	Format	Notes
30619F2D-0F54-41BD-A65A-7588D8C85B45$_{16}$	Read, Notify,Indicate		
7D2A4BDA-D29B-4152-B725-2491478C5CD7$_{16}$	write		

Table 50: *Vector's serial service characteristics*

APPENDIX D

Servers & Data Schema

This Appendix describes the servers that Vector contacts[9]

Server	Description & Notes
chipper.api.anki.com:443	The speech recognition engine lives here
conncheck.global.anki-services.com/ok	Used to check to see if it can connect to Anki
jdocs.api.anki.com:443	Storage of some sort of data. Name, faces, prefs?
token.api.anki.com:443	Used to get the API certificate.[10]
https://anki.sp.backtrace.io:6098	Vector posts crashes to this server
https://sqs.us-west-2.amazonaws.com/792379844846/DasProd-dasprodSqs-1845FTIME3RHN	This is used to synchronize with data analytics services.
https://ota.global.anki-services.com/vic/prod/	Where Vector checks for updates
https://ota.global.anki-dev-services.com/vic/rc/lo8awreh23498sf/	For the Developer branch
amazon.com/code	Where does the visual go?

Table 51: *The servers that Vector contacts.*

The servers that the mobile app contacts:

TBD

[9] Todo: sync up with info at: https://github.com/anki-community/vector-archive
[10] XYZ had a write up, reference that.

APPENDIX E

Phrases and their Intent

This Appendix maps the published phrases that Vector responds to and their intent:

Table 52: *The "Hey Vector" phrases*

Intent	Phrase
movement_backward	Back up
imperative_scold	Bad robot
	Be quiet
global_stop	Cancel the timer
check_timer	Check the timer
imperative_come	Come here
imperative_dance	Dance.
play_popawheelie	Do a wheelstand
imperative_fetchcube	Fetch your cube
imperative_findcube	Find your cube
play_fistbump	Fist Bump
play_fistbump	Give me a Fist Bump
movement_backward	Go backward
explore_start	Go explore
movement_forward	Go forward.
movement_turnleft	Go left
movement_turnright	Go right
	Go to sleep
	Go to your charger
	Good afternoon
greeting_goodbye	Goodbye
	Good evening
	Good night
greeting_goodmorning	Good morning

imperative_praise	Good robot
seasonal_happyholidays	Happy Holidays
seasonal_happynewyear	Happy New Year
greeting_hello	Hello
	He’s behind you
character_age	How old are you
imperative_abuse	I hate you.
knowledge_question	I have a question …
imperative_love	I love you.
imperative_apology	I’m sorry.
play_blackjack	Let’s play Blackjack
	Listen to music
imperative_lookatme	Look at me
	Look behind you
	My name is [Your Name]
imperative_negative	No
play_anygame	Play a game
play_anytrick	Play a trick
play_blackjack	Play Blackjack
play_pickupcube	Pick up your cube.
play_popawheelie	Pop a wheelie.
play_rollcube	Roll your Cube
	Run
set_timer	Set a timer for [length of time]
explore_start	Start Exploring
	Stop Exploring
global_stop	Stop the timer
take_a_photo	Take a picture of [me/us]
take_a_photo	Take a picture
take_a_photo	Take a selfie
movement_turnaround	Turn around
movement_turnleft	Turn left
movement_turnright	Turn right
imperative_volumelevel	Volume [number].
imperative_volumedown	Volume down
imperative_volumeup	Volume up.
	Volume maximum

names_ask	What's my name?
weather_response	What's the weather in [City Name]?
weather_response	What's the weather report?
show_clock	What time is it?
imperative_affirmative	Yes

Note: Vector's NLP server doesn't recognize "home" ..

Questions

Table 53: *The Vector questions phrases*

Subject	**Example Phrase**
Current conversion	What's 1000 Yen in US Dollars?
Flight status	What is the status of American Airlines Flight 100?
Equation solver	What is the square root of 144?
General knowledge	What is the tallest building?
places	What is the distance between London and New York?
People	Who is Jarvis?
Nutrition	How many calories are in an avocado?
Sports	Who won the World Series?
Stock market	How is the stock market?
Time zone	What time is it in Hong Kong?
Unit conversion	How fast is a knot?
Word definition	What is the definition of Artificial Intelligence?

APPENDIX G

File system

This Appendix describes files systems

As the Vector uses the Android bootloader, it reuses – or at least reserves – many of the Android partitions[11] and file systems. Many are probably not used. Quotes are from Android documentation.

The file system table tells use where they are stored in the partitions, and whether they are non volatile.

Mount point	Partition name	Description & Notes
/	BOOT_A	The primary linux kernel and initramfs
/data[12]	USERDATA	The data created for the specific robot (and user) that customizes it. A factory reset wipes out this user data. This portion of the file system is encrypted using "Linux Unified Key Setup" (LUKS).
/firmware	MODEM	The firmware for the WiFi/Bluetooth radio
/factory	OEM	Customizations, such as bootloader property values. … Or the factory recovery?
/persist	PERSIST	Device specific "data which shouldn't be changed after the device is shipped, e.g. DRM related files, sensor reg file (sns.reg) and calibration data of chips; wifi, bluetooth, camera etc."
/media/ram /run /var/volatile /dev/sm		Internal temporary file systems; holds temporary files, interprocess communication

***Table 54:** The file system mount table*

The partition table found on the Vector:

Partition name	Size	Description & Notes
ABOOT	1 MB	The application bootloader, which may load the kernel, recovery, or fastboot.
ABOOTBAK	1 MB	The application bootloader, which may load the kernel, recovery, or fastboot.
BOOT_A	32 MB	The primary linux kernel and initramfs.
BOOT_B	32 MB	The backup linux kernel and initramfs.
CONFIG	512 KB	Configuration of TBD.
DDR	32 KB	Configuration of the DDR RAM.
DEVINFO	1 MB	"device information including: is_unlocked (aboot), is_tampered, is_verified, charger_screen_enabled, display_panel, bootloader_version, radio_version etc. Contents of this partition are displayed by "fastboot oem device-info" command

***Table 55:** The partition table*

[11] https://forum.xda-developers.com/android/general/info-android-device-partitions-basic-t3586565
[12] This is mounted by "mount-data.service' The file has a lot of information on how it unbricks

		in human readable format. Before loading boot.img or recovery.img, bootloader verifies the locked state from this partition."
EMR	16 MB	????
FSC	1KB	"Modem FileSystem Cookies"
FSG	1.5 MB	Golden backup copy of MODEMST1, used to restore it in the event of error
KEYSTORE	512 KB	"Related to [USERDATA] Full Disk Encryption (FDE)"
MISC	1MB	"a tiny partition used by recovery to communicate with bootloader store away some information about what it's doing in case the device is restarted while the OTA package is being applied. It is a boot mode selector used to pass data among various stages of the boot chain (boot into recovery mode, fastboot etc.). e.g. if it is empty (all zero), system boots normally. If it contains recovery mode selector, system boots into recovery mode."
MODEM	64 MB	Binary "blob" for the WiFi/Bluetooth radio firmware
MODEMST1	1.5MB	Binary "blob" for the WiFi/Bluetooth radio firmware
MODEMST1	1.5MB	Binary "blob" for the WiFi/Bluetooth radio firmware
OEM	16MB	Customizations, such as bootloader property values.
PAD	1MB	"related to OEM"
PERSIST	64MB	Device specific "data which shouldn't be changed after the device is shipped, e.g. DRM related files, sensor reg file (sns.reg) and calibration data of chips; wifi, bluetooth, camera etc."
RECOVERY	32 MB	An alternate partition holding systems applications and libraries that let the application boot into a mode that can download a new system. Often used to wipe out the updates.
RECOVERYFS	640 MB	An alternate partition holding systems applications and libraries that let the application boot into a mode that can download a new system. Often used to wipe out the updates.
RPM	512KB	The primary for resource power management[?]
RPMBAK	512KB	The backup for resource power management[?]
SBL1	512KB	Secondary bootloader. Responsible for loading ABOOT; may also have an "Emergency" download mode.
SBL1BAK	512KB	Secondary bootloader. Responsible for loading ABOOT; may also have an "Emergency" download mode.
SEC	16KB	The secure boot fuse settings, OEM settings, signed-bootloader stuff
SSD	8KB	"Secure software download" for secure storage, encrypted RSA keys, etc
SYSTEM_A	896MB	The (primary) systems applications and libraries with application specific code.
SYSTEM_B	896MB	The bakcup systems applications and libraries with application specific code.
SWITCHBOARD	16 MB	????
TZ	768KB	The TrustZone of key-value pairs, encrypted by the hardware and other keys
TZBAK	768KB	The TrustZone of key-value pairs, encrypted by the hardware and other keys
USERDATA	768MB	The data created for the specific robot (and user) that customizes it. A factory reset wipes out this user data. This partition is encrypted using "Linux Unified Key Setup" (LUKS).

The files employed in the Vector binaries:

Table 56: *Files*

File	Description
/anki/etc/version	
/data/data/com.anki.victor	
/data/data/com.anki.victor/cache/crashDumps	
/data/etc/localtime	The time zone
/data/misc/bluetooth/abtd.socket	The IPC socket interface to Bluetooth LE
/data/unbrick	
/dev/block/bootdevice/by-name/emr	
/dev/spidev0.0	The SPI channel to communicate with the IMU
*/dev/socket/_anim_robot_server_*	The IPC socket with Vector's animation controller
*/dev/socket/_engine_gateway_server_*	The IPC socket interface to Vector's Gateway [TBD] server
*/dev/socket/_engine_gateway_proto_server_*	The IPC socket interface to Vector's Gateway [TBD] server
*/dev/socket/_engine_switch_server_*	The IPC socket interface to Vector's Switchbox [TBD] server
/dev/ttyHS0	Console log? (but then, where is the connection to the base-board?)
/factory/cloud/something.pem	
/proc/sys/kernel/random/boot_id	A random identifier, created each boot
/sys/devices/system/cpu/possible[13] */sys/devices/system/cpu/present*	The number of CPUs and whether they can be used.
/data/data/com.anki.victor/cache/crashDumps	Parameters and values specific to the ST LIS2DH accelerometer
/run/anki-crash-log	
/run/das_allow_upload	
/run/fake-hwclock-cmd[14]	Sets the fake time to the time file (Vector doesn't have a clock)
/run/fault_code	
/tmp/data_cleared	
/tmp/vision/neural_nets	

[13] https://www.kernel.org/doc/Documentation/ABI/testing/sysfs-devices-system-cpu
[14] https://manpages.debian.org/jessie/fake-hwclock/fake-hwclock.8.en.html