Suitability of a Common ZigBee Radio Module for Interaction and ADL Detection

Jakob Neuhaeuser(✉), Tim C. Lueth, and Lorenzo T. D'Angelo

Institute of Micro Technology and Medical Device Technology,
Technische Universitaet Muenchen Garching, Garching, Germany
Jakob.neuhaeuser@tum.de

Abstract. In this contribution we analyze whether it is possible to use a ZigBee module to detect interactions. The detection is done using modules with adjustable communication range. From the data we want to draw conclusions about the activities of daily living (ADL). This is important to detect because small changes in behavior which might indicate the beginning of dementia or a mild cognitive impairment. We have already done promising experiments with a radio module. In this paper we analyze whether it is also possible to use a common ZigBee module. Therefore we compare it with the module we used already and then modify the antenna to shorten the range. Our findings show that it is possible to use the ZigBee module for interaction and ADL detection by adjustable range after modifications in the antenna circuit.

Keywords: Interaction · ADL · Radio module · Recognition zigbee

1 Introduction

As more and more people are getting older, it is increasingly important to detect illnesses like dementia at an early stage. Alzheimer dementia is usually a chronic illness characterized by a reduction in memory recall and mental performance and the implications this has for everyday activities (ADL) [1]. In order to measure the ADL objectively, we measure sADL (simple ADL) [2] through interactions between radio modules with scale able transmission range. In this paper we want to discuss whether it is possible to use a standard ZigBee module for our purpose and which modifications are necessary.

2 State of the Art

At the moment ADL are assessed through ADL scales like the Barthel Index [3], in order to determine the autonomy of a person. The data for the Index is collected by interviewing the patient about his or her ability to carry out daily routines. If possible the patient is interviewed, if not a relative or a nurse provides the data. The greatest disadvantage is the subjectivity which was proven amongst others by [4] and [5].

In research various projects are developing systems able to detect different ADLs automatically. In this article we want to focus on radio based systems. A lot of work

I. Stojmenovic et al. (Eds.): MOBIQUITOUS 2013, LNICST 131, pp. 576–587, 2014.
DOI: 10.1007/978-3-319-11569-6_45

was done on RFID-based systems. Here the advantage is that the transponders do not need their own energy source like a battery, because the energy is obtained from the RFID-Reader. Reference [6] for example, developed a glove and, later on, a wristband equipped with RFID readers [7]. The systems have a reading range of about 10 cm. UHF RFID, tags called WISPs, have a read range up to 10 m but have problems with orientation [8]. Another approach, which will be explained later on in detail, is to use a scalable transmission range of 0,5 m to 5 m to tag different objects. By wearing a recording device different interactions with objects can be monitored [9]. ZigBee was so far only used as a network system to collect Activities of Daily Living through different sensors like accelerometers and reed relay [10].

For our concept with different transmission ranges (see Sect. 3) it is important to use a radio module with a scalable transmission range. Therefore we took to a closer look at the systems available on the market (Table 1).

Table 1. Different radio modules with programmable transmission range (from datasheet)

Manufacturer	Model	Steps	min dBm	max dBm
Ingenieurbuero	RT868F4	4	−8	10
Laird Technologies	LT2510	4	8	17
IMST	iM201A	4	−18	0
IMST	iM871A	8	−8	13
amber-wireless	AMBZ420	16	−28	4,5
IMST	iM860A	16	−50	10
Atmel	**ATZB-24-A2**	**16**	**−17**	**3**
Nanotron	**NanoLOC**	**64**	**−36**	**0**

We did not find a lot of radio modules with scalable transmission ranges. Especially the ones which have different ranges are only adjustable in a few discrete steps, for example 4 or 8. The one we are using is adjustable in 64 steps (NanoLOC by Nanotron); the Zigbee module investigated in this paper has at least 16 (ATZB-24-A2 by Atmel).

3 Materials and Methods

The concept of our system is inspired by human communication [11]. When we talk, the volume of our voice is always chosen in such a way that the people one is talking to, but not all the people in the room, can hear. Reference [12] already applied this approach in robotics on infrared, to realize local communication between robots. Similar to this, we tag different objects and people who broadcast their own ID with different transmission ranges. In the first step we would like to give every object a specific transmission range (r_{sADL}), but later on, this can be dynamic, like the volume of our voice. Additionally, we define two different types of modules: the active-mote which sends out its ID and can receive and save other IDs and the passive-mote which can only send out its ID. With two active-motes (a, b) having different positions $p_{a/b}$ in a room, three different states can be concluded:

$$p_a \begin{pmatrix} x_a \\ y_a \\ z_a \end{pmatrix}; p_b \begin{pmatrix} x_b \\ y_b \\ z_b \end{pmatrix}; r_{sADL_a} > r_{sADL_b} \tag{1}$$

State 1: Both motes are outside the transmission range of each other:

$$|p_a - p_b| > r_{sADL_a} > r_{sADL_b} \tag{2}$$

State 2: Only one mote can "hear" the other:

$$r_{sADL_a} > |p_a - p_b| > r_{sADL_b} \tag{3}$$

State 3: Both motes can "hear" the other:

$$r_{sADL_a} > r_{sADL_b} > |p_a - p_b| \tag{4}$$

The event E_a is generated when the distance of both motes is smaller than the transmit range r_{sADLa}:

$$|p_a - p_b| < r_{sADL_a} \Rightarrow E_a \tag{5}$$

The event together with the duration is interpreted as a sADL (simple Activities of Daily Living [2]) and saved.

This concept was realized using a NanoLOC radio module [9] and evaluated in a day hospital [13]. Because of the module not being a mass product and also having a high power consumption of over 33 mA in RX mode, in this paper we want to evaluate whether the ZigBit Module from Atmel which needs only 19 mA in RX mode, is also suitable.

To check whether ZigBee with a scalable transmission range is applicable to detect sADL (simple Activities of Daily Living) a ZigBit module was implemented. The radio module ATZB-24-A2 from Atmel was chosen due to a transmission range scalable in 17 steps. The module consists of a microcontroller and a radio module with a double chip antenna (Fig. 1,1). Additionally we use a real-time-clock for time keeping (Fig. 1,2), as well as a flash-memory for data storage (Fig. 1,4) and an accelerometer (Fig. 1,3) as additional information source. The energy is stored in a 250 mAh li-po battery with charge controller (Fig. 1,5). As interface we chose a 30 pin connector (Fig. 1,6).

As it is intended for the modules being able to work within a ZigBee network, the program of the modules is based on Atmels ZigBit stack. The base mote, from which the data can be collected later on, is the coordinator that builds up the network. All other motes are children of the base. This is the reason why our network has the depth of one. The base can communicate directly with all other motes, when they are reachable. The active-motes can also communicate via peer2peer because they are

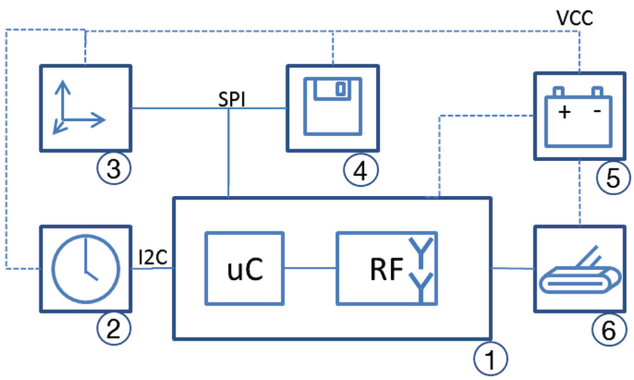


Fig. 1. Hardware setup: (1) ZigBit radiomodule with microcontroller and a double antenna/ Nanoloc moudle with microcotnroller (2) Real time clock (3) Accelerometer, (4) Flash memory, (5) Battery with chargecontrol, (6) Connector

implemented as router. The passive-mote can only send messages to the active-mote and is not able to receive messages from them as it is implemented as an end device. But the end device is still able to receive messages from the coordinator, which is not needed so far (see Fig. 2).

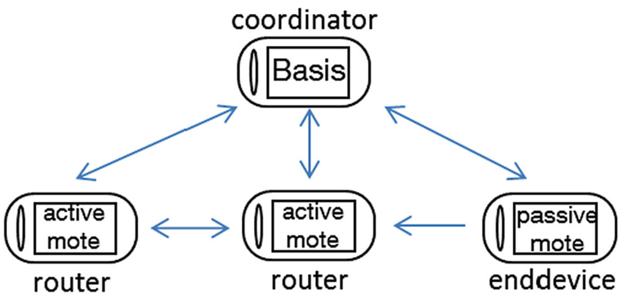


Fig. 2. Concept for using the system within the ZigBee-Standard

4 Validation

In the first step we evaluated our existing system with the Nanoloc-module. For that we took two of our modules called Eventlogger and enlarged the distance between both, step by step. To have less disruptions we mounted the modules on tripods. One module was sending out a message for 30 times and with the other module we checked how many of them were recognized (Fig. 3).

The results of the different transmission power compared to the distance are shown in Table 2. The green area is a recognition of over 90 % of the messages, yellow means less and red means none of the messages were received.

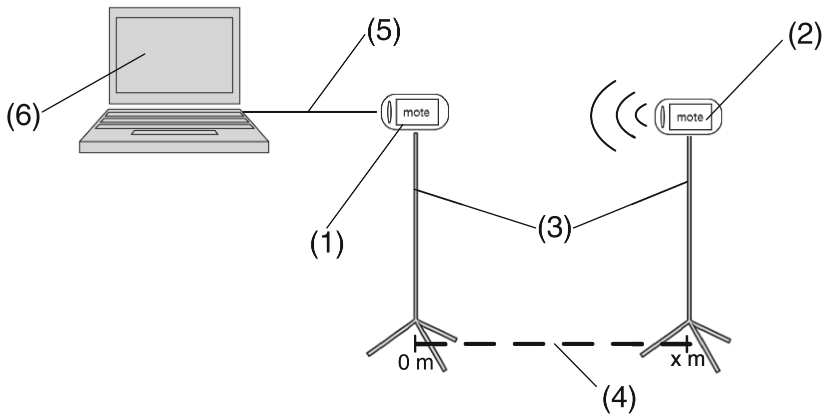


Fig. 3. Experiment for ranges of different transmission power steps of the Nanoloc-Module; sender-module (2) receiver-module (1), tripod (3) measured distance (4); interface cable and PC (5,6)

Although there are some gaps you find a tendency for a bigger transmission range with higher transmission power. The gaps are getting smaller when the system is tested in real environment. Therefore we mounted one module on the wall and the second one was worn by a test person. The procedure was the same as in the first experiment with the only difference that we took less transmission power values.

Table 3 shows the outcome of the experiment. Here it can be seen quite well that it is possible to vary the transmission range between 0.3–5 m in 29 steps.

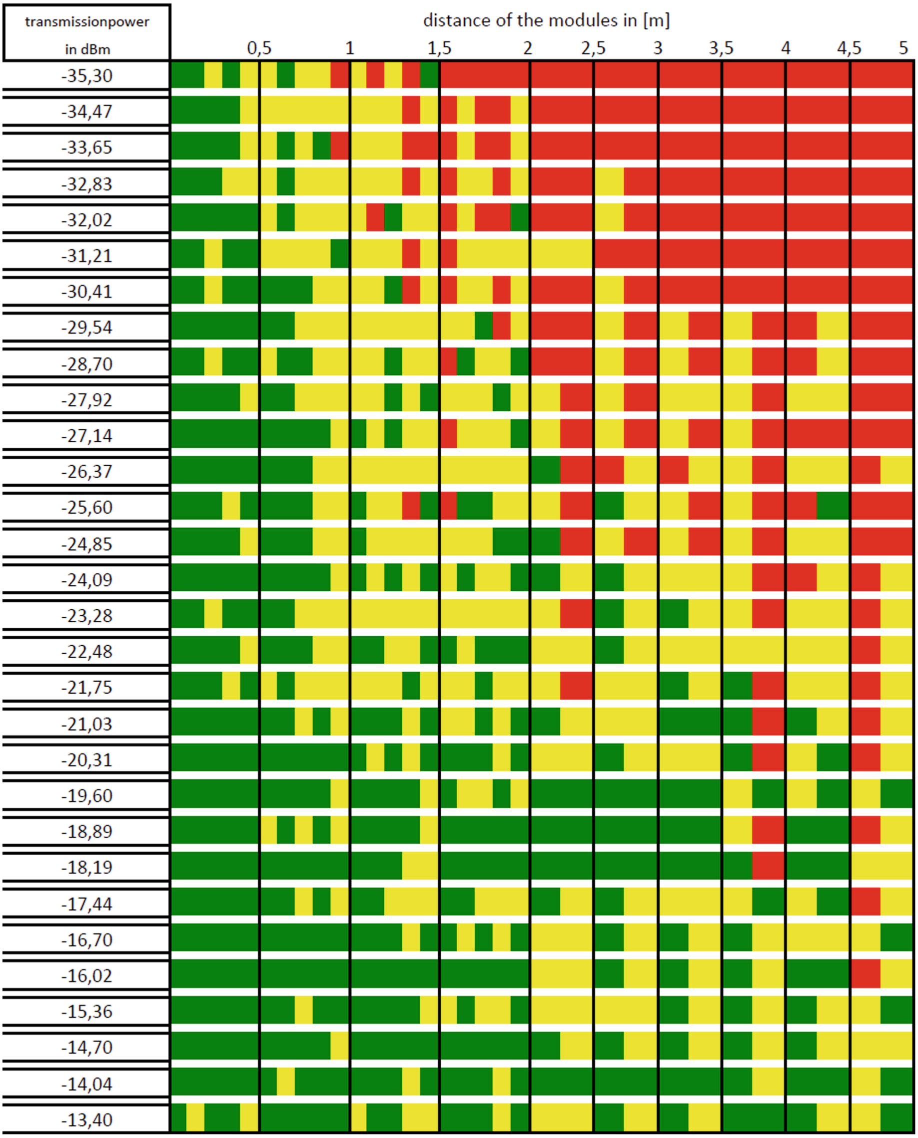
The desired aim of the experiment with the Zigbee-Module would be to get the same or even better results than the ones we got form the Nanotron-Module.

In the first experiment with the Zigbee-Module we analyzed the RSSI-Value (Received Signal Strength Indication). The RSSI-Value sometimes is used to measure the distance between two radio modules. It is also known that it is not very accurate due to effects like fading. To check the RSSI-Value we took two of our modules and enlarged the distance between both, step by step. This was done with full and low transmission power. We measured the value for every distance 10 times and calculated the arithmetic average (Fig. 5).

As we saw problems in determining the distance based on the RSSI-value between 1,25 to 5 m another solution had to be found. In the next step the transmission range of the ZigBee Module was analyzed. As the module is intended to be used in homes and the range at the lowest transmission power is over 15 m, this does not meet our requirement of a transmission range between 0.5 and 5 m. Therefore we modified the antenna in order to reduce the transmission range. The receiving power of the receiver is influenced by the distance of transmitter and receiver, the power of the transmitter, the antenna gain of the transmitter and of the receiver. This is shown by Eq. 6:

$$P_R = P_T \left(\frac{\lambda}{4\pi d} \right)^{\alpha} G_R \, G_T \tag{6}$$

Table 2. Measured range of the module at different transmission power steps green: full reception (>90 %), yellow: reception in part, red: no reception (0 %)



P_R Power receiver, P_T Power transmission, λ wave length
d distance, G_R/G_T antenna gain receiver/transmitter
α materia and frequency dependent coefficent

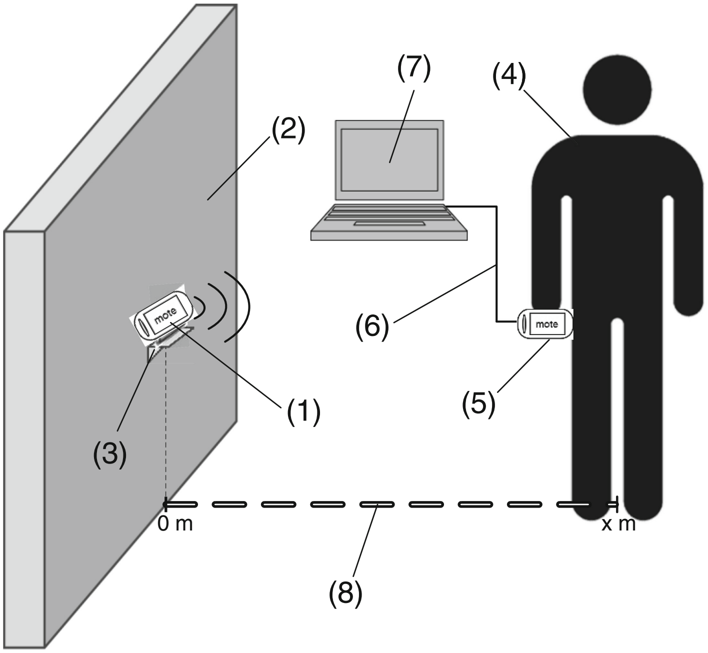
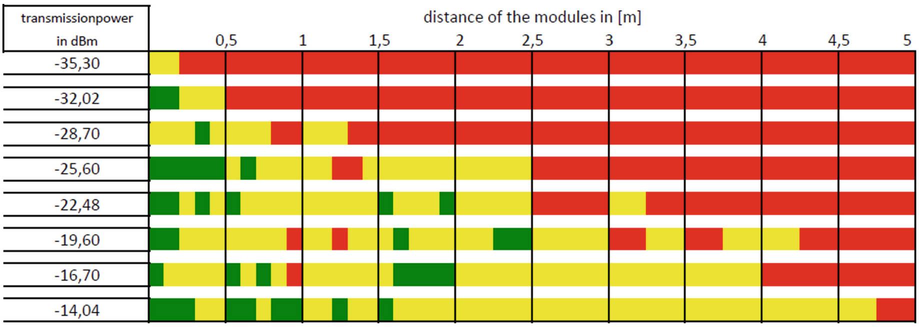


Fig. 4. Experiment for real environment. Sender module (1) mounted (3) on a wall (2); test person (4) with receiver module (5); measured distance (8); interface cable and PC (6,7)

Table 3. Transmitted range of different transmission power steps (green: full reception (>90 %), yellow: reception in part, red: no reception (0 %))



By reducing the power of the transmitter or the sensitivity of the receiver, the communication range can be reduced. Both effects are achieved by reducing the effectiveness of the antenna (Eq. 7).

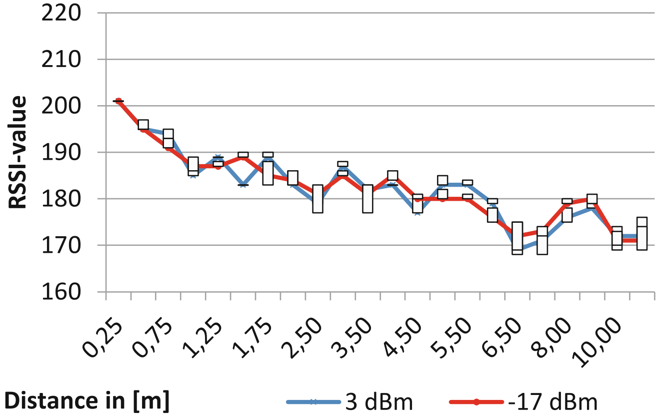


Fig. 5. RSSI-value over 10 values compared to the distance between the two modules

$$\eta = \frac{R_S}{R_S + R_V} \tag{7}$$

R_S *radiation resistance*, R_V *ohmic resistance*

Due to the effectiveness of the antenna being influenced by the resistance of the feed cable, it is possible to vary it by adding an additional resistor in the feed cable. Figure 4 shows the dependency of the maximal transmission range of different resistors (Fig. 6).

In the next step we modified both modules, as the receiving power is also modified by the resistance. The best suitable output for our requirements was achieved at 39 Ω (Fig. 7).

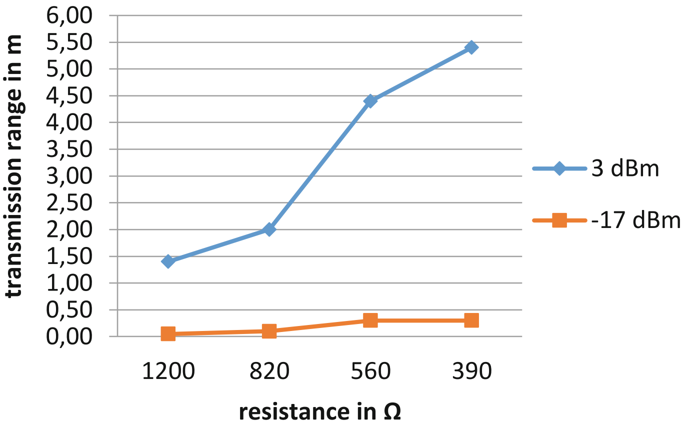


Fig. 6. Adding different resistances in the feed cable of the antenna to change its effectiveness, resulting in a reduction of transmission range

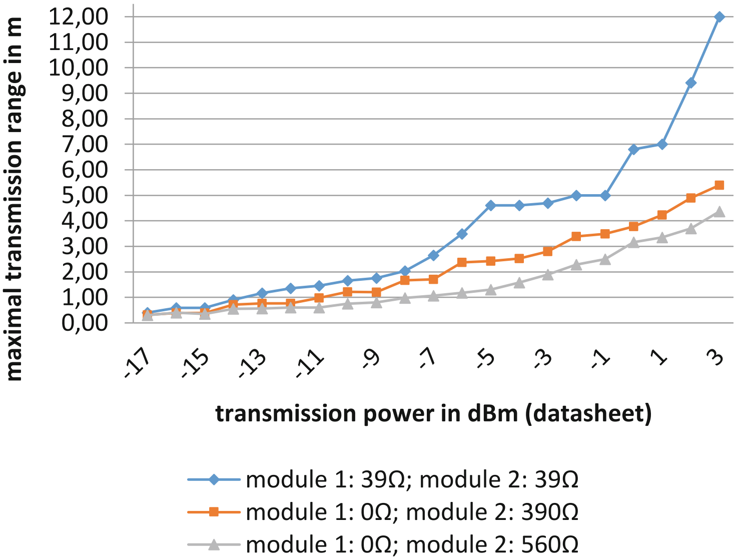


Fig. 7. Maximal transmission range for each adjustable transmission power (dBm out of the datasheet)

As we now had the correct range, the next step was to evaluate the reliability of the system using the 17 different transmission power settings. Therefore one module was set to transmit an ID as well as a consecutive number every 500 ms. The second module was set to receive the ID and to count how many IDs had to be sent in order to receive 10 messages. The distance between both modules was raised step by step. The outcome is shown in Table 4.

In our last experiment we checked once again the RSSI-value with the modified antenna. The RSSI values are displayed in Table 5.

We see that the RSSI-value changes only at a distance of 0.25 m.

5 Results

The experiments with the NanoLoc Module as well as our already published papers show that it is possible to obtain information about a person interacting with objects marked with modules with different transmission ranges. With the experiment we showed that there is a significant difference between measurements ideal conditions and nearly real conditions. With the first experiment together with the Zigbee Module we found out that the RSSI-value is not accurate enough for our demands, since it is not suited to distinguish distances between 1–5 m. The RSSI-value only changes significantly up to a distance of one meter. Since the module is created for wide ranges the power steps of the module were far over 15 m. Therefore we modified the antenna with a resistor at 39 Ω in order to get a communication range from 50 cm to some meters. The closer look at the reliability of the transmission range showed that there are also

Table 4. Reliability of the ZigBit-Module with a disturbed antenna (39 Ω) green: full reception (>90 %), yellow: reception in part, red: no reception (0 %)

Table 5. RSSI-value over 10 measurements at different distances

Distance in m	0,25	0,5	0,75	1,0	1,25	1,5	1,75	2,0	2,25	2,5
RSSI-value over 10	171	166	165	165	165	165	165	165	165	165

distances where there is very stable communication followed by distances with an unstable communication. An interesting point in the last experiment is the RSSI-Value at small distances. At very near contact the RSSI-Value is still different, this could be used to detect close contact with a tagged object.

6 Conclusion

The experiments in this paper only consider communication in one alignment (all modules were oriented face to face). They show that it is possible to modify the antenna of a ZigBee module in order to get a transmission range from 50 cm to some meters.

This is the first step to be able to detect interactions for different reading ranges. The difficulty on the market is that only modules with wide ranges are available so it is not easy to find a module with short ranges. The ZigBee module can be used for the detection of activities after these modifications. The advantage of using the ZigBee standard would be the possibility to combine our system with e.g. household appliances such as the oven. Here it would be imaginable to switch on the oven only when the person is nearby. The second advantage is the modules price, as ZigBee transceivers are more and more becoming a mass product. One remaining challenge is that the circuit leads to the loss of the approval, therefore using the ZigBee module is currently still no valid alternative for our existing module.

Acknowledgments. The research is supported by Alfried Krupp von Bohlen und Halbach-Stiftung.

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