The United States of America

The Director of the United States Patent and Trademark Office

Has received an application for a patent for a new and useful invention. The title and description of the invention are enclosed. The requirements of law have been complied with, and it has been determined that a patent on the invention shall be granted under the law.

Therefore, this

United States Patent

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Michelle K. Lee

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(12) United States Patent
Sulc

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(45) Date of Patent: Apr. 4, 2017

(54) **SYSTEM FOR MESSAGE ACKNOWLEDGEMENT AND DATA COLLECTION IN WIRELESS MESH NETWORKS**

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H04L 12/721 (2013.01)
H04L 12/733 (2013.01)

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CPC ***H04W 40/20*** (2013.01); *H04L 45/122* (2013.01); *H04L 45/32* (2013.01)

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CPC H04W 40/20; H04L 45/122; H04L 45/32
USPC 370/256, 315, 400
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,905,234 A 2/1990 Childress et al.
5,471,471 A 11/1995 Freeburg et al.
5,602,843 A * 2/1997 Gray H04W 84/16 370/338
5,815,732 A 9/1998 Cooper et al.
5,842,124 A 11/1998 Kenagy et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CZ 2008-288 A3 11/2009

OTHER PUBLICATIONS

Sulc et al., "IQMESH, Technology for Wireless Mesh Networks: Implementation Case Studies", ICNS 2012, Published on Mar. 25, 2012.*

(Continued)

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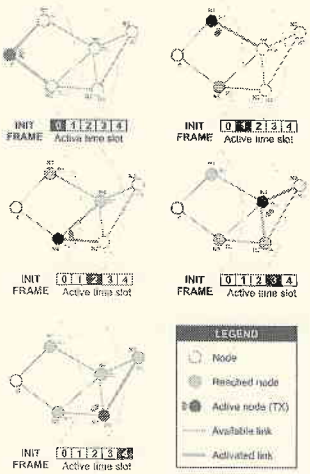
(57) **ABSTRACT**

A slave communication device includes a memory and a processor for operation within a wireless mesh network of communication devices including a control communication device. The memory stores a virtual routing identifier assigned to the slave communication device in response to increasing range from the control communication device. The processor, in response to receiving an initiation message from a control communication device, initiates data collection from said slave communication device synchronized relative to the start of the initiation message frame by, cumulatively setting bits in a first acknowledgement message in response to content of a second acknowledgement message received from another slave communication device. The first acknowledgement message being synchronized with start of the initiation message frame and the processor initiates communication of the first acknowledgement message to a destination in a time slot selected in response to the assigned virtual routing identifier.

20 Claims, 4 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

7,304,587	B2 *	12/2007	Boaz	H04Q 9/00 340/870.02
9,179,498	B2 *	11/2015	Sulc	H04L 61/35
2003/0109218	A1	6/2003	Pourkeramati et al.	
2003/0204560	A1	10/2003	Chen et al.	
2004/0085965	A1	5/2004	Fotedar	
2004/0167708	A1	8/2004	Jenkins et al.	
2004/0215752	A1	10/2004	Satapati et al.	
2005/0025179	A1	2/2005	McLaggan et al.	
2006/0165015	A1	7/2006	Melick et al.	
2007/0004344	A1	1/2007	DeGroot et al.	
2007/0188343	A1	8/2007	Sulc	
2007/0268127	A1 *	11/2007	Rittle	G08B 25/10 340/539.22
2008/0273542	A1	11/2008	Hagiwara et al.	
2008/0285601	A1	11/2008	Sherrer et al.	
2010/0002700	A1	1/2010	Simpson, Jr.	
2012/0008542	A1 *	1/2012	Koleszar	H04L 45/32 370/312
2012/0163234	A1 *	6/2012	Sulc	H04L 61/35 370/254
2012/0209951	A1 *	8/2012	Enns	H04L 29/08729 709/217

OTHER PUBLICATIONS

Lee SH., Lee KW., Cho YZ. "Directional Flooding Scheme with Data Aggregation for Energy-Efficient Wireless Sensor Networks" (2008) In: VazãT., Freire M.M., Chong I. (eds) Information Networking. Towards Ubiquitous Networking and Services. ICOIN 2007. Lecture Notes in Computer Science, vol. 5200. Springer, Berlin, Heidelberg.*

Fei Hu, Xiaojun Cao, Carter May "Optimized Scheduling for Data Aggregation in Wireless Sensor Networks" (Apr. 2005), IEEE International Conference on Networking, Sensing and Control.*

* cited by examiner

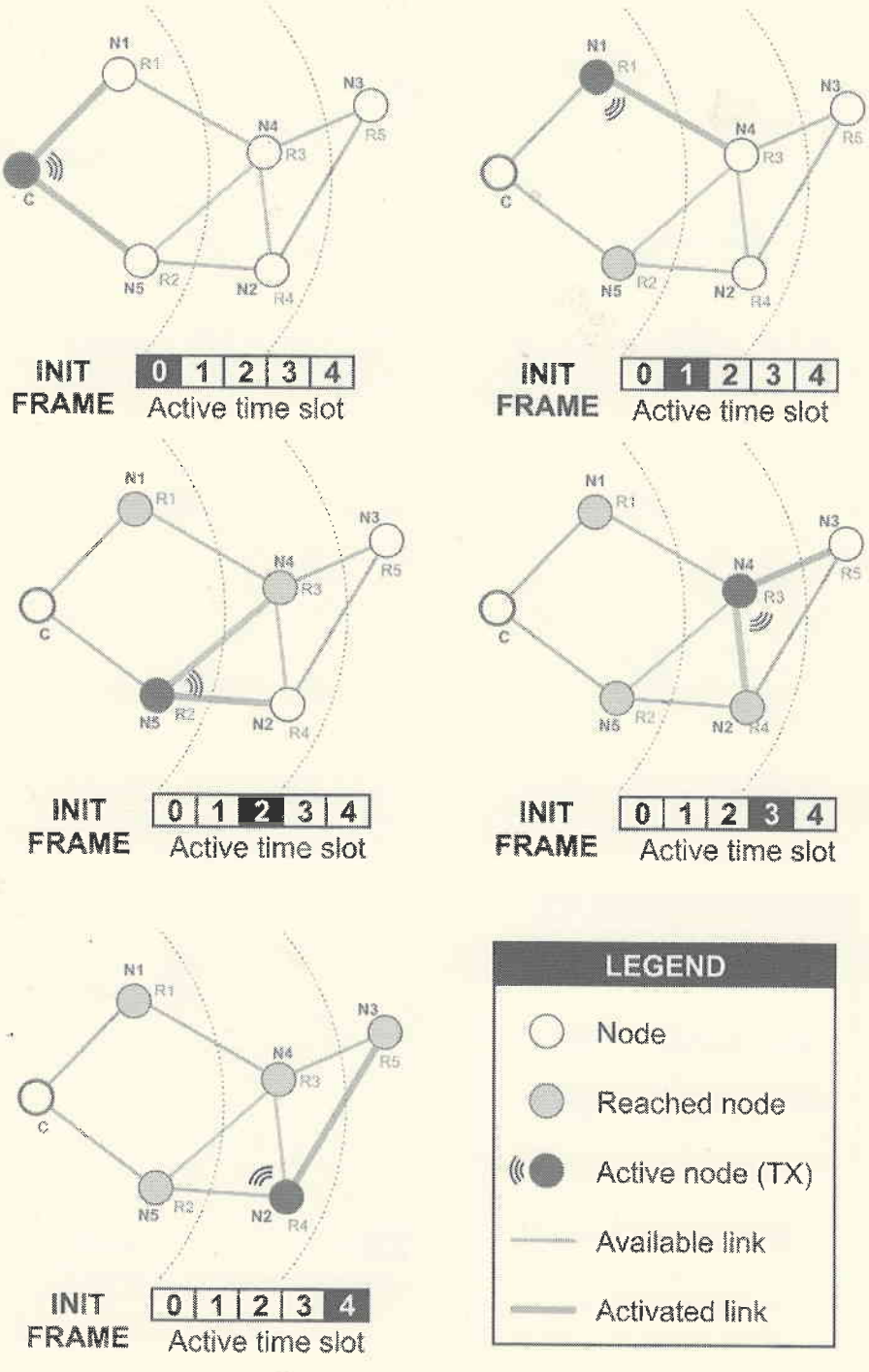

N1
R1
N3
R5
N4
R3
C
N5
R2
N2
R4
INIT FRAME
0 1 2 3 4
Active time slot
LEGEND
Node
Reached node
Active node (TX)
Available link
Activated link

FIG. 1A

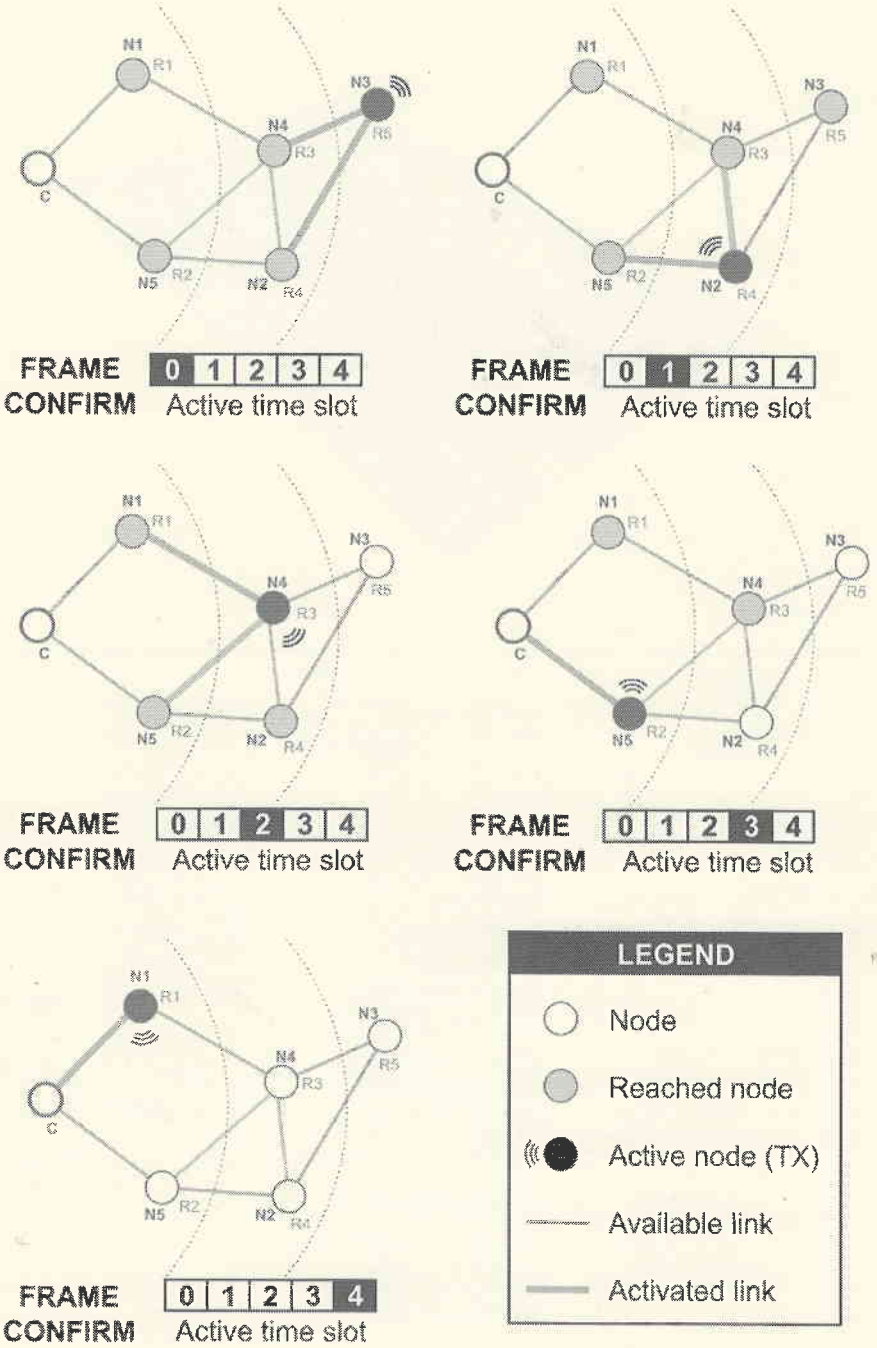
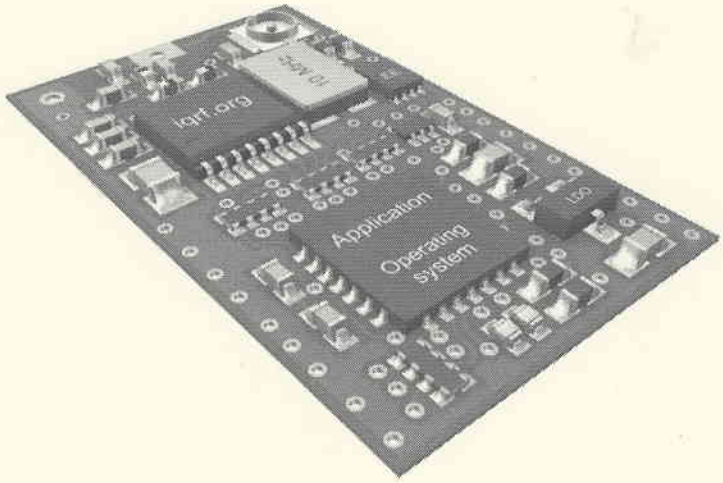

N1
R1
N3
R5
N4
R3
C
N5
R2
N2
R4
FRAME CONFIRM
0 1 2 3 4
Active time slot
LEGEND
Node
Reached node
Active node (TX)
Available link
Activated link

FIG. 1B


iqrf.org
Application
Operating system
LDO

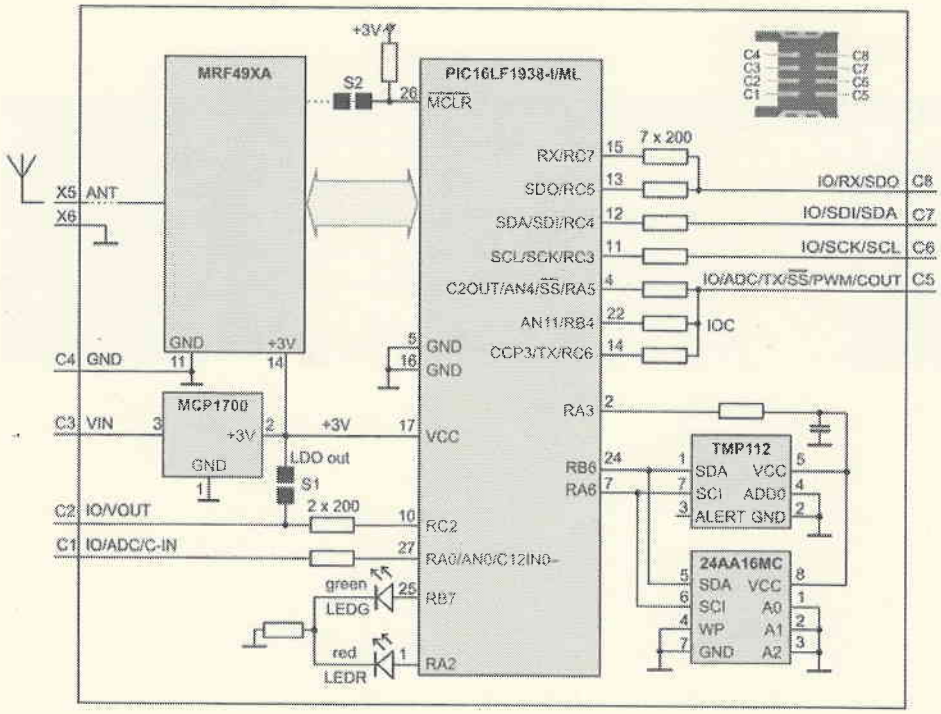

MRF49XA
PIC16LF1938-I/ML
MCLR
S2
+3V
X5 ANT
X6
GND
+3V
C4 GND
C3 VIN
MCP1700
LDO out
S1
2 x 200
C2 IO/VOUT
C1 IO/ADC/C-IN
RX/RC7
SDO/RC5
SDA/SDI/RC4
SCL/SCK/RC3
C2OUT/AN4/SS/RA5
AN11/RB4
CCP3/TX/RC6
VCC
RC2
RA0/AN0/C12IN0-
RB7
RA2
RA3
RB6
RA6
7 x 200
IO/RX/SDO C8
IO/SDI/SDA C7
IO/SCK/SCL C6
IO/ADC/TX/SS/PWM/COUT C5
IOC
TMP112
SDA VCC
SCL ADD0
ALERT GND
24AA16MC
SDA VCC
SCL A0
WP A1
GND A2
green
LEDG
red
LEDR

FIG. 2

Figure 3

Acknowledgement frame																																				
							data in the individual devices after receiving transmission of the active device																													
slot	active	sent data					data in N1					data in N2					data in N3					data in N4					data in N5					data in C				
0	N3	0	0	3	0	0	1	0	0	0	0	0	2	3	0	0	0	0	3	0	0	0	0	3	4	0	0	0	0	0	5	0	0	0	0	0
1	N2	0	2	3	0	0	1	0	0	0	0	0	2	3	0	0	0	0	3	0	0	0	2	3	4	0	0	2	3	0	5	0	0	0	0	0
2	N4	0	2	3	4	0	1	2	3	4	0	0	2	3	0	0	0	0	3	0	0	0	2	3	4	0	0	2	3	4	5	0	0	0	0	0
3	N5	0	2	3	4	5	1	2	3	4	0	0	2	3	0	0	0	0	3	0	0	0	2	3	4	0	0	2	3	4	5	0	2	3	4	5
4	N1	1	2	3	4	0	1	2	3	4	0	0	2	3	0	0	0	0	3	0	0	0	2	3	4	0	0	2	3	4	5	1	2	3	4	5