Wireless-Enabled Remote Patient Monitoring Solutions

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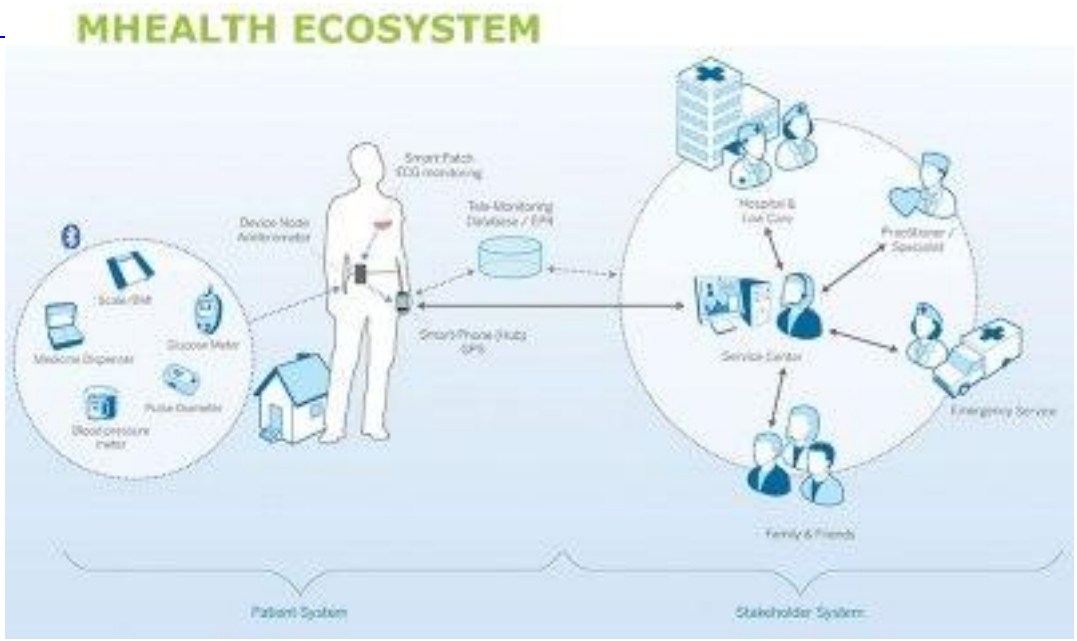
The remote patient monitoring field is a rapidly growing one given the advantages it offers for home healthcare, remote regions, and elderly care. However, with it comes a long list of considerations and critical issues for designers and engineers to keep in mind. This article offers a "bird's eye view" of this sector and many of the factors on which to maintain focus.



[1]The last decade has seen a rapid growth and adoption of mobile computing devices, such as smartphones and tablets; they cannot be missed from the view of the healthcare industry. Healthcare providers, clinicians, and medical device manufacturers are seeking new and innovative ways to use these powerful platforms to improve the quality of patient care and lower healthcare costs. A major area where this is directly impacting the patient consumer is in remote patient monitoring (RPM) solutions. The Continua Health Alliance (www.continuaalliance.org) defines RPM as a technology that enables the monitoring, evaluation and management of an individual through a remote interface that collects clinical data from the individual (e.g., vitals, blood pressure, etc.) and then transmits the data to a remote healthcare provider for clinical review, care management, and patient education. Figure 1 illustrates the mHealth Ecosystem and RPM.

Several factors make this trend for RPM all the more interesting:

- Helping to avoid unnecessary readmissions per the Affordable Care Act of 2010 and Hospital Readmissions Reduction Program, thus saving money for

insurance companies, CMS, and healthcare providers (legislation and healthcare reform states that patients readmitted within 30 days result in providers not getting reimbursed and even penalized)
- Wireless technologies enabling various RPM possibilities
- Helping to alleviate a major problem in the United States (e.g., a shortage of healthcare professionals among health-insured populations)

	TYPICAL FUNCTIONS AND ACTIVITIES	PAYERS
Wellness and Prevention	• Measure weight, exercise, calories consumed	• Consumer/family • Caregiver (adult child or parent) • Employer/plan sponsor
Chronic Disease Management	• Diabetes: monitor blood glucose • CHF: track weight • Hypertension: track blood pressure • COPD: measure strength of breath (spirometry) • General: medication adherence	• Health plan • Employer/plan sponsor • Provider (pay-for-performance or bundled-for-condition)
Acute Care, Post-Acute Care, and Rehabilitation	• Prevent hospital readmission • Monitor physical therapy at home	• Medicare, under Accountable Care Act • Health plan • Employer/plan sponsor
Aging at Home	• Medication optimization • Remote monitoring of vital signs and activities of daily living • Assistive technologies (e.g., smart home, smart wheelchair)	• Health plan • Consumer/family

Market Needs and Opportunities

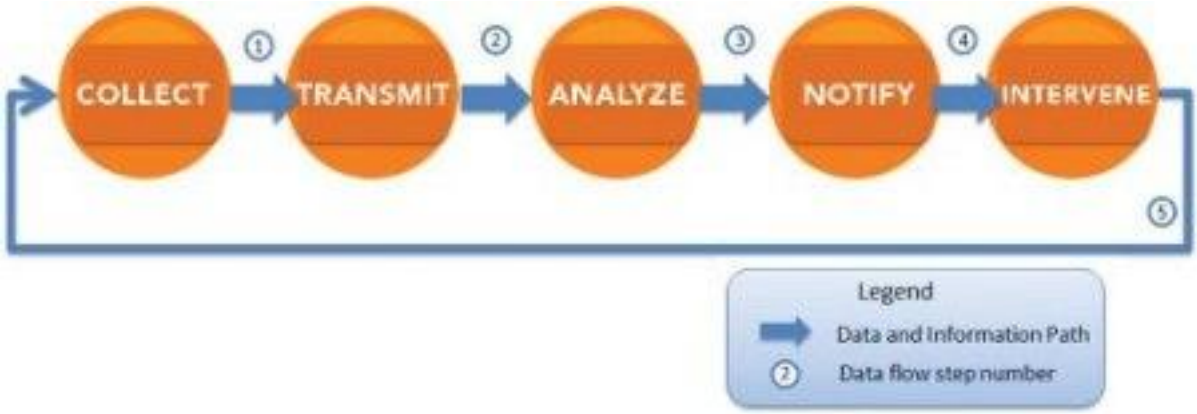
Research has shown that the U.S. market for advanced patient monitoring systems has grown from $3.9 billion in 2007 to $8.9 billion in 2011 and is forecast to reach $20.9 billion by 2016. Efforts to reduce costs in healthcare, avoid emergency room overcrowding, and prepare for a growing number of elderly patients in the years to come are a few of the drivers for the adoption of these systems.[1]

Ubiquity and the real-time nature of mobile networks provide an excellent means to connect patients to healthcare providers and payers to suppliers and regulators. The unique value of the RPM system is its openness and flexibility. The healthcare provider can build the most appropriate “toolbox” for a given patient’s monitoring needs and conversely, the consumer patient will experience the healthcare oversight they have paid for but have been missing.

So what opportunities exist for RPM solutions? Table 1 summarizes monitoring opportunities.

Typical RPM Process Flow

The typical RPM process flow in Figure 2 supports the medical segments listed in Table 1. The steps involve:



Collecting Data

Typically the care provider prescribes only required devices to manage care, as confirmed by Drs. Ilene Klein and Pallabi Sanyal[4,5], that are wirelessly enabled for external monitoring (e.g., blood pressure monitor). The patient conducts tests per the healthcare provider's orders (e.g., steps on scale once a day, performs blood pressure test in the morning and mid-day, or simply monitors in the case of some on-body sensors). Note that the frequency of activating sensors may vary for a single patient over time as their condition changes (i.e., gets better or worse).

An example of devices (Figure 3) for RPM of congestive heart failure (CHF) or post-acute care/rehabilitation includes:

- Scale: Rapid variations in weight (within days) are symptomatic of a non-homeostatic system and possible health complications.
- SpO2: Peripheral oxygen saturation in blood along with pulse, as indicators of respiratory failure or hypoxia
- Thermometer: Indicator of body status (normal or in distress)
- Heart rate monitor: Flags arrhythmias (tachycardia, bradycardia, etc.)
- Blood pressure cuff: Indicator of hypotension, prehypertension, hypertension, etc.
- Stethoscope: A wirelessly enabled stethoscope could prove beneficial for remote analysis. Basic analysis can also be performed by patient per provider's instructions.
- ECG monitor: Post-heart attack and/or post-surgery arrhythmia monitoring
- Camera/video: Enables provider to assess quality of respirations, color, and level of consciousness, as well as, depending on rehab, see gait or other rehab parameters. Also, it enables coaching.

Transmitting Data

After data has been collected successfully, it needs to be transmitted by wireless, cellular, or wired means to an Internet cloud-based platform for evaluation or further processing by the respective parties.

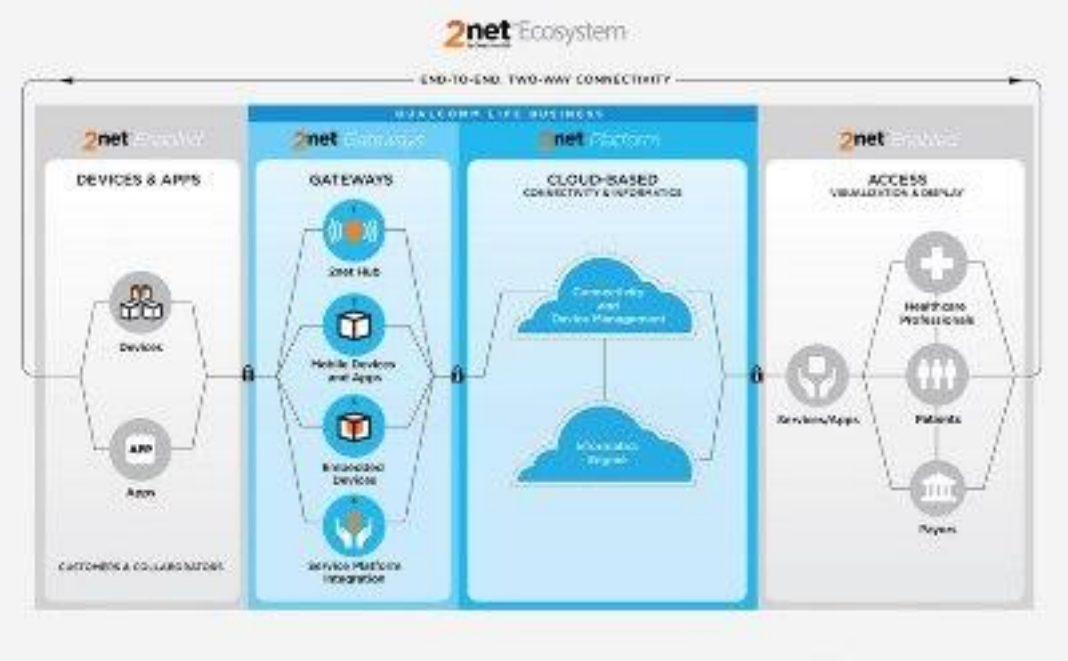
Analyze, Notify, and Intervene

These steps provide the necessary feedback loop to the healthcare provider, caregiver, and patient (and in some cases, family members), and play a critical role in the effectiveness and success of the solution as a whole.

RPM Wireless Health Solutions

Broadly speaking, today, the following deployment architectures for wireless health solutions in RPM can be observed.

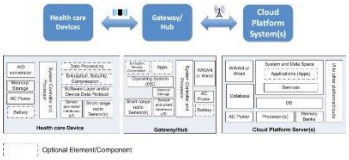
1. Medical device with embedded cellular
2. Medical device with short-range sensor that wirelessly connects with an mHealth gateway or hub device that provides wireless cellular capabilities (e.g., Qualcomm Life's 2net Hub [2])
3. Medical device or accessory interface with mobile device (e.g., smartphone, tablet) with embedded cellular
4. Cloud/server-to-cloud/server connectivity and integration



[3]As an example, Figure 4 shows Qualcomm Life's 2net ecosystem, which encapsulates the multiple deployment architectures. To delve a bit deeper into a specific design, the diagram in Figure 5 presents an example reference architecture for solution #2. In designing such solutions, some of the key considerations are:

Healthcare Device and Hub

- Simple operation and minimal user interface
- Plug-and-play operation with associated devices
- One or more short-range wireless radio sensors [e.g., Bluetooth (BT), Wi-Fi, Zigbee]
- Sensing and/or software interfaces (I/F) that are typically connected to a main controller system either through digital connections (e.g., SPI, I^2C interfaces) or some form of multi-channel general purpose analog to digital converters (A/D)
- The controller/processor system is the brain and performs some key tasks that include:
    - Read the data from the multiple sensors with respect to each one's timing requirement, package this data together after security encoding, and process the data
    - Store as well as send the data out to a short-range, wireless transceiver
    - Packaging and time stamping the data generated from various sources at various rates
    - Some form of power savings and management schemes that range from the simple to the sophisticated
- On-board memory storage for system and healthcare/app data (e.g., Flash)
- Power supply (if AC power based) and/or battery
- WWAN chip or module for wireless cellular connectivity



[4]

- Operating system software and application software need to coordinate numerous hardware components, communicate with various devices, interface with the wireless cellular network carrier, perform administrative tasks, and manage memory and data.

Additional Aspects for the Hub

- Versatile wireless connectivity options for short-range radio technologies to communicate and collect the biometric data in some concurrent fashion across multiple devices
- Appropriate security measures (e.g., data encryption safeguards, mechanisms so the hub communicates only to authorized healthcare devices)
- Over-the-air (OTA) software updates for hubs in remote locations (e.g., in the home) by the associated or other cloud platform
- Selection of the carrier for providing communication between the hub and the cloud platform involves consideration for:
    - Targeted geo-market(s) and cellular technologies
    - Wider availability and lower cost of the wireless module
    - Increased coverage
    - Flexibility and availability of data plan costs
- On the medical and wireless fronts, securing appropriate certifications and approvals from regulatory agencies (e.g., FDA), industry (e.g., BT SIG), and carrier (e.g., Verizon, AT&T, Vodafone)

Cloud Platform

Some of the broad capabilities the platform is intended to provide are:

- Secure protocol to ensure data integrity over the communication channel
- Best-in-class end-to-end safety, security, and privacy controls on transfer and storage of data
- A secure and robust cloud-based platform with capabilities for data storage, back-up, and disaster recovery
- Managed services for hubs
- Two-way communication
- Secure private cellular link to the cloud
- Managing and monitoring the wireless cellular network
- Secure data centers, such as compliance with payment card industry
- Database and repository’s (e.g., Oracle 11g)
- Device management, including activation and provisioning
- Management of OTA software updates

- Tiers two and three customer support
- Traffic overage management and carrier billing reconciliation
- Web-services application interfaces for gateway management (e.g., representational state transfer)

Conclusion

As we can see, RPM is an exciting, emerging space that will gain adoption in the coming years. While much has already been accomplished technologically, there is much that still needs to be done so patients and providers feel trust and peace of mind with such solutions, particularly around aspects of safety, security, privacy, accuracy, and integrity of their data. By putting the power into the hands of the patient community and needy participants, not only is relief provided to the burdened healthcare system, but also patient consumers are empowered to participate in managing their own healthcare.

References

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Links:

[1] http://www.mdtmag.com/sites/mdtmag.com/files/legacyimages/Figure1_0.jpg
[2] http://www.qualcommlife.com/
[3] http://www.mdtmag.com/sites/mdtmag.com/files/legacyimages/Figure4.jpg
[4] http://www.mdtmag.com/sites/mdtmag.com/files/legacyimages/Figure5.jpg
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