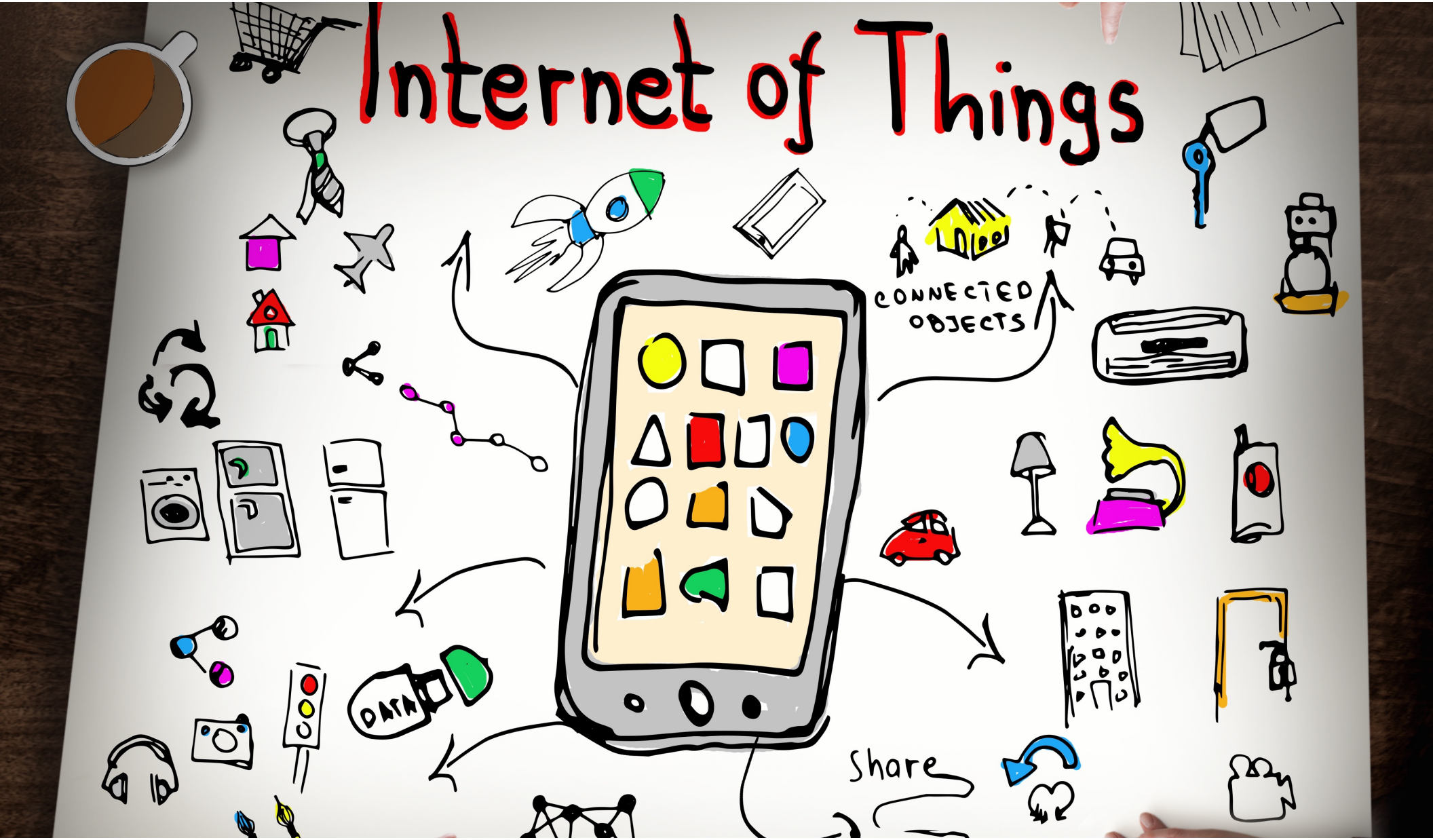
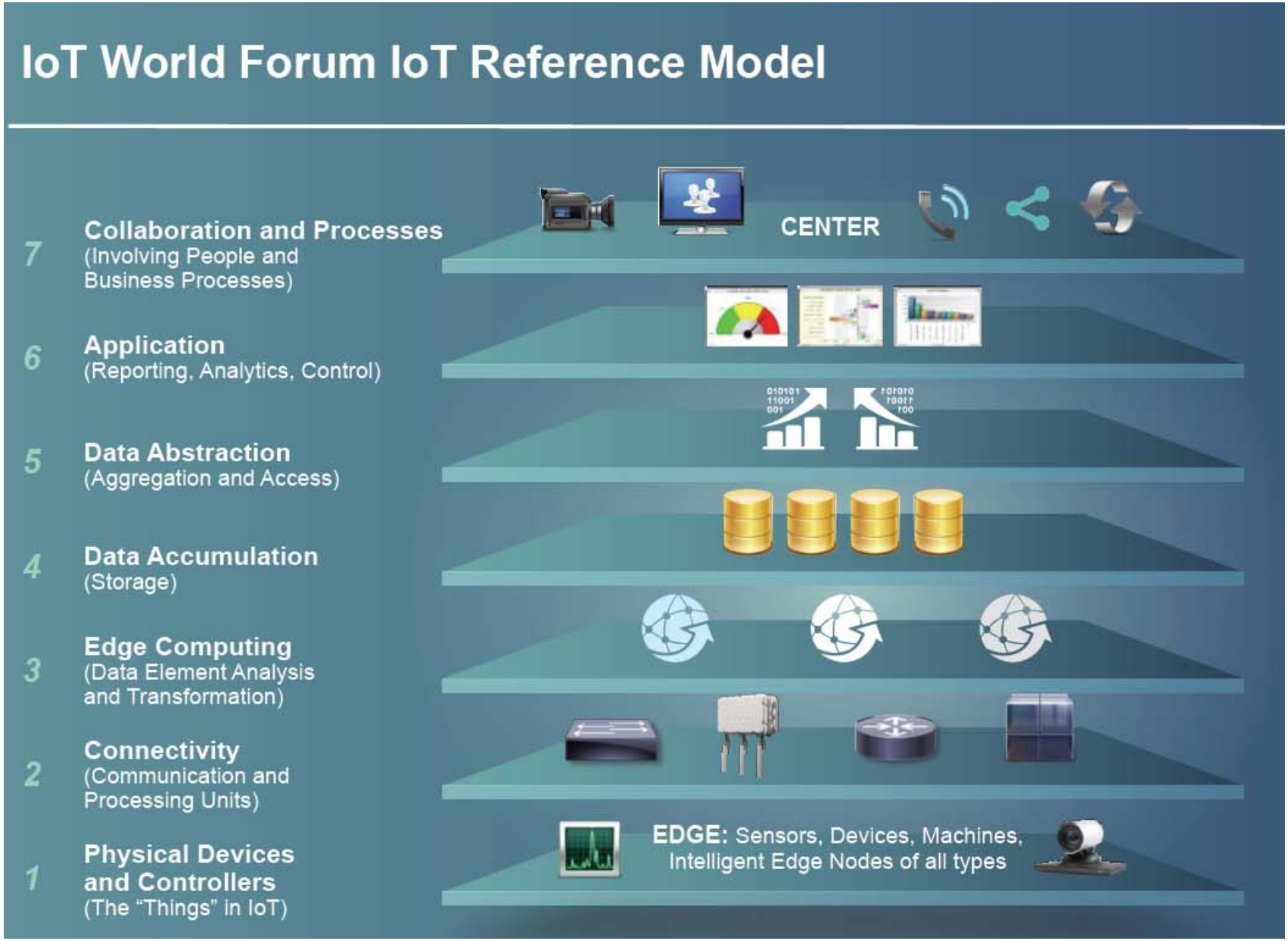


Sports Analytics

18-738 Sports Technology

Priya Narasimhan
ECE Department
Carnegie Mellon University
@yinzcampriya

Overview


IoT World Forum IoT Reference Model
7
Collaboration and Processes
(Involving People and Business Processes)
6
Application
(Reporting, Analytics, Control)
5
Data Abstraction
(Aggregation and Access)
4
Data Accumulation
(Storage)
3
Edge Computing
(Data Element Analysis and Transformation)
2
Connectivity
(Communication and Processing Units)
1
Physical Devices and Controllers
(The "Things" in IoT)
CENTER
EDGE: Sensors, Devices, Machines, Intelligent Edge Nodes of all types

Big Data

- On the list of most ambiguous terms in 2012 (Global Language Monitor)
- Most searched term amongst clients (gartner.com)

- Gartner led the way early in recognizing the value and the opportunity
- **The three "V"s of big data, coined by Gartner in 2001**
- **Volume**: Growing quantity of data (social media, video, biometric, etc.)

Sheer size of data.

- **Velocity**: Quickening speed of data (sensors, smart meters, etc.)
- **Variety**: Increasing types of data (mobile apps, desktop, etc.)

Big Data

Volume

Transaction-based data stored over time, unstructured data from social media, and sensor and machine-to-machine data are examples of large volumes of data that can be easily and inexpensively stored in the cloud. However, with decreased storage costs comes new issues: How do you determine relevance and use analytics to create value from your data?

Velocity

Data is streaming at unprecedented speeds, and it's becoming increasingly difficult to process it in a timely manner. Sensors, smart metering and RFID tags drive the need to deal with torrents of data. As SAS notes, "Reacting quickly enough to deal with data velocity is a challenge for most organizations."

Variety

Data comes in many formats. Some is structured and in numeric databases. Unstructured data include documents, email, video, financial transactions, social posts or customer preferences. "Managing, merging and governing different varieties of data is something many organizations still grapple with," SAS says.

What is the purpose of big data?

Making better informed decisions
e.g. strategies, recommendations

Discovering hidden insights
e.g. anomalies forensics, patterns, trends

Automating business processes
e.g. complex events, translation

Business Amplification

Source: Gartner

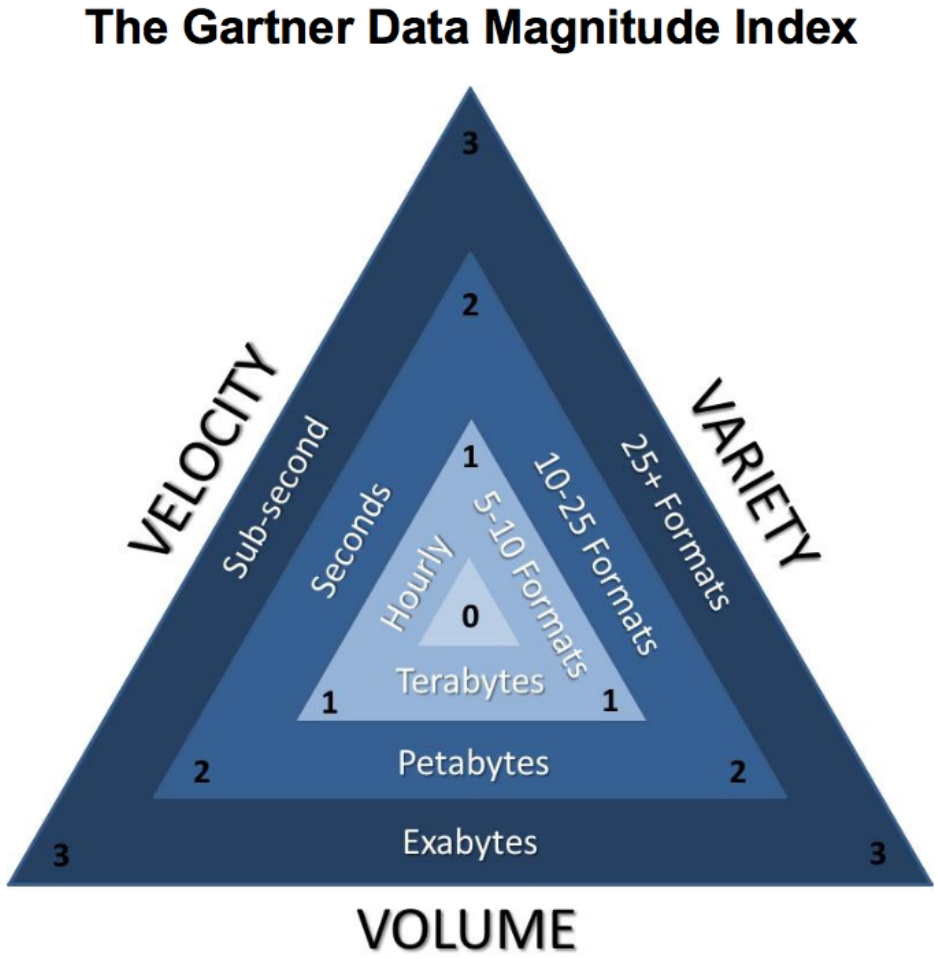
How about an actual definition?

Big data are high **volume**, **velocity** and/or **variety** of information assets which require cost-effective, innovative forms of information processing **to enable** enhanced insight discovery, decision- making, and process optimization.

Gartner's definition in 2012

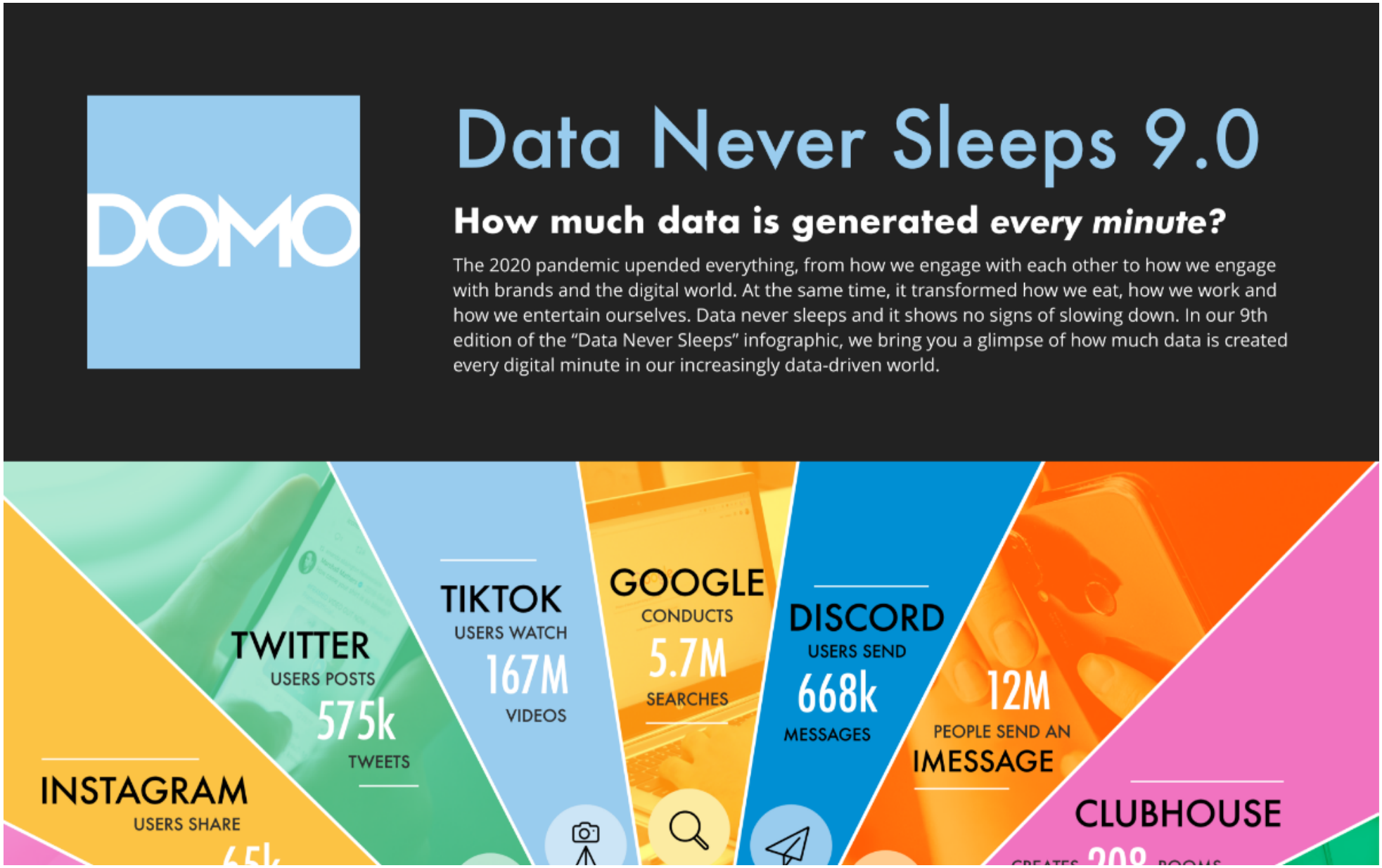
Just how “big” is Big?

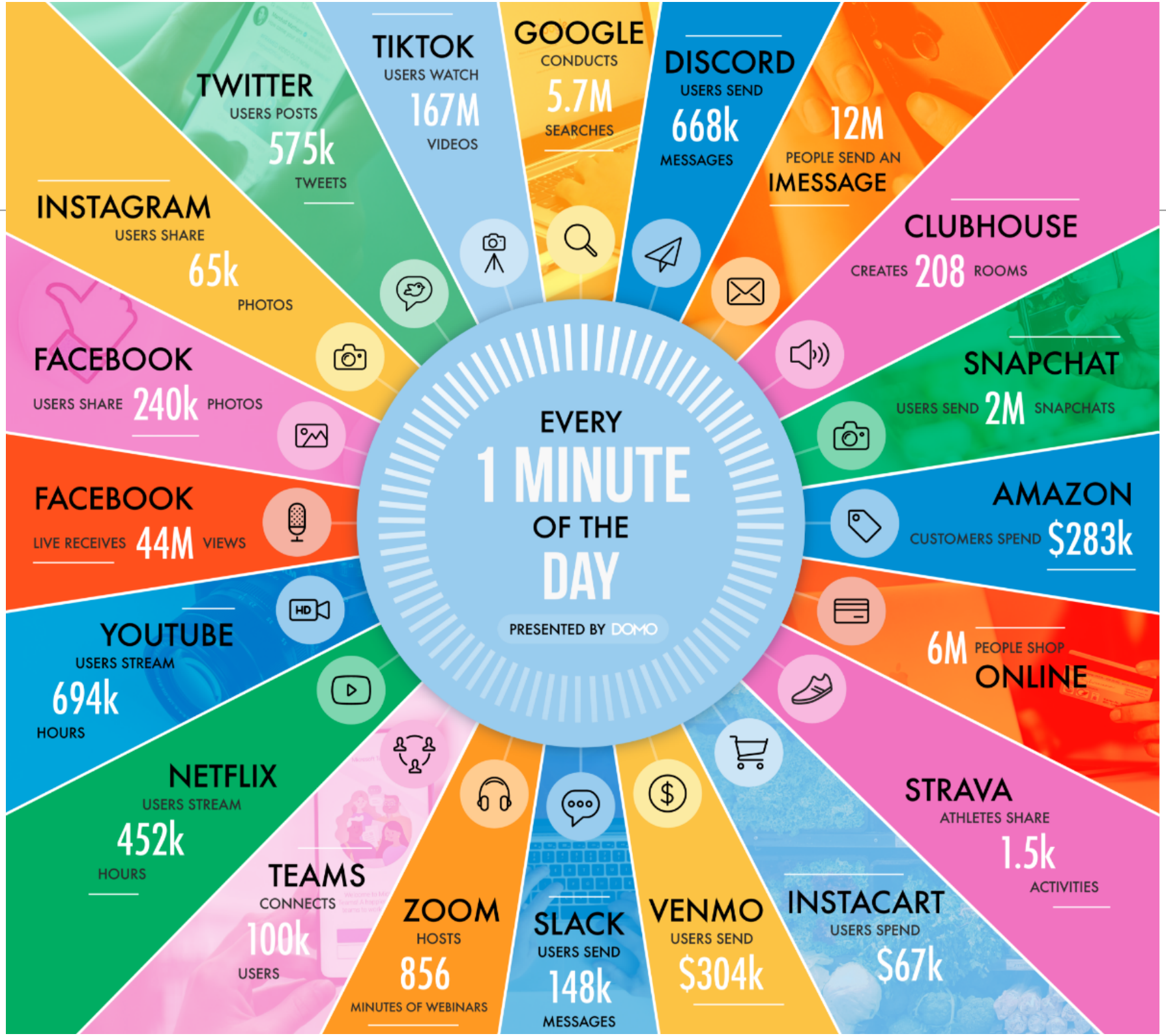
- Gartner Data Magnitude Index attempts to define the three axes
- You add up the numbers to arrive at the DMI
- DMI 1-3: “Traditional” data
- DMI 4-6: Today’s state of the art
- DMI 7-9: Where we are headed



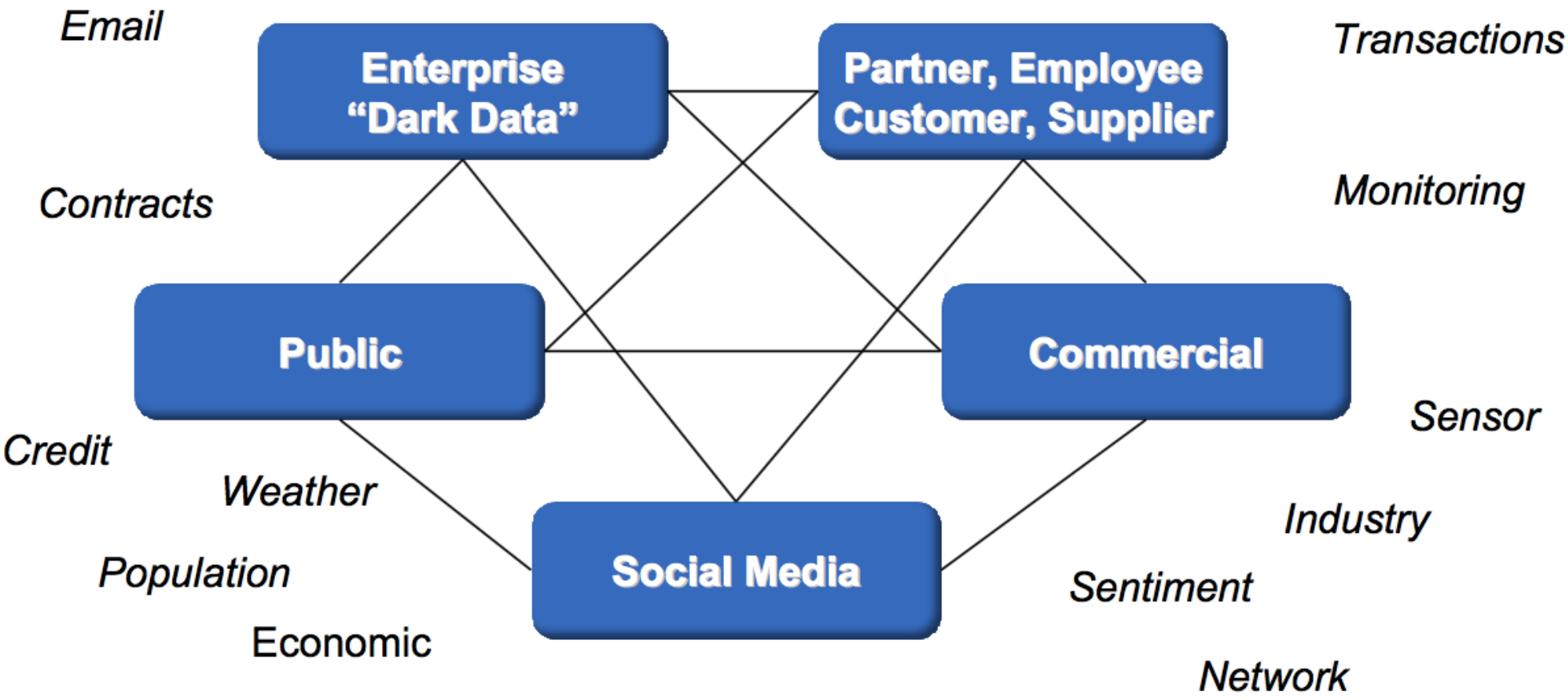
Source: Gartner

Just how “big” is Big?




EVERY
1 MINUTE
OF THE
DAY
PRESENTED BY DOMO
TWITTER
USERS POSTS
575k
TWEETS
TIKTOK
USERS WATCH
167M
VIDEOS
GOOGLE
CONDUCTS
5.7M
SEARCHES
DISCORD
USERS SEND
668k
MESSAGES
12M
PEOPLE SEND AN
IMESSAGE
CLUBHOUSE
CREATES 208 ROOMS
INSTAGRAM
USERS SHARE
65k
PHOTOS
FACEBOOK
USERS SHARE 240k PHOTOS
SNAPCHAT
USERS SEND 2M SNAPCHATS
FACEBOOK
LIVE RECEIVES 44M VIEWS
AMAZON
CUSTOMERS SPEND $283k
YOUTUBE
USERS STREAM
694k
HOURS
6M PEOPLE SHOP
ONLINE
NETFLIX
USERS STREAM
452k
HOURS
STRAVA
ATHLETES SHARE
1.5k
ACTIVITIES
TEAMS
CONNECTS
100k
USERS
ZOOM
HOSTS
856
MINUTES OF WEBINARS
SLACK
USERS SEND
148k
MESSAGES
VENMO
USERS SEND
$304k
INSTACART
USERS SPEND
$67k

And where does this data come from?



Source: Gartner

Structured vs. Unstructured data

POS : Point of Sale. Structured data is point of sale data.

Structured
(inside the business)

- **POS** — What's selling, how much does it cost, who's buying it
- **Suppliers** — Product availability, prices
- **Accounting** — Costs, revenue, margins
- **Labor** — Wages, salaries, tips

Unstructured
(outside the business)

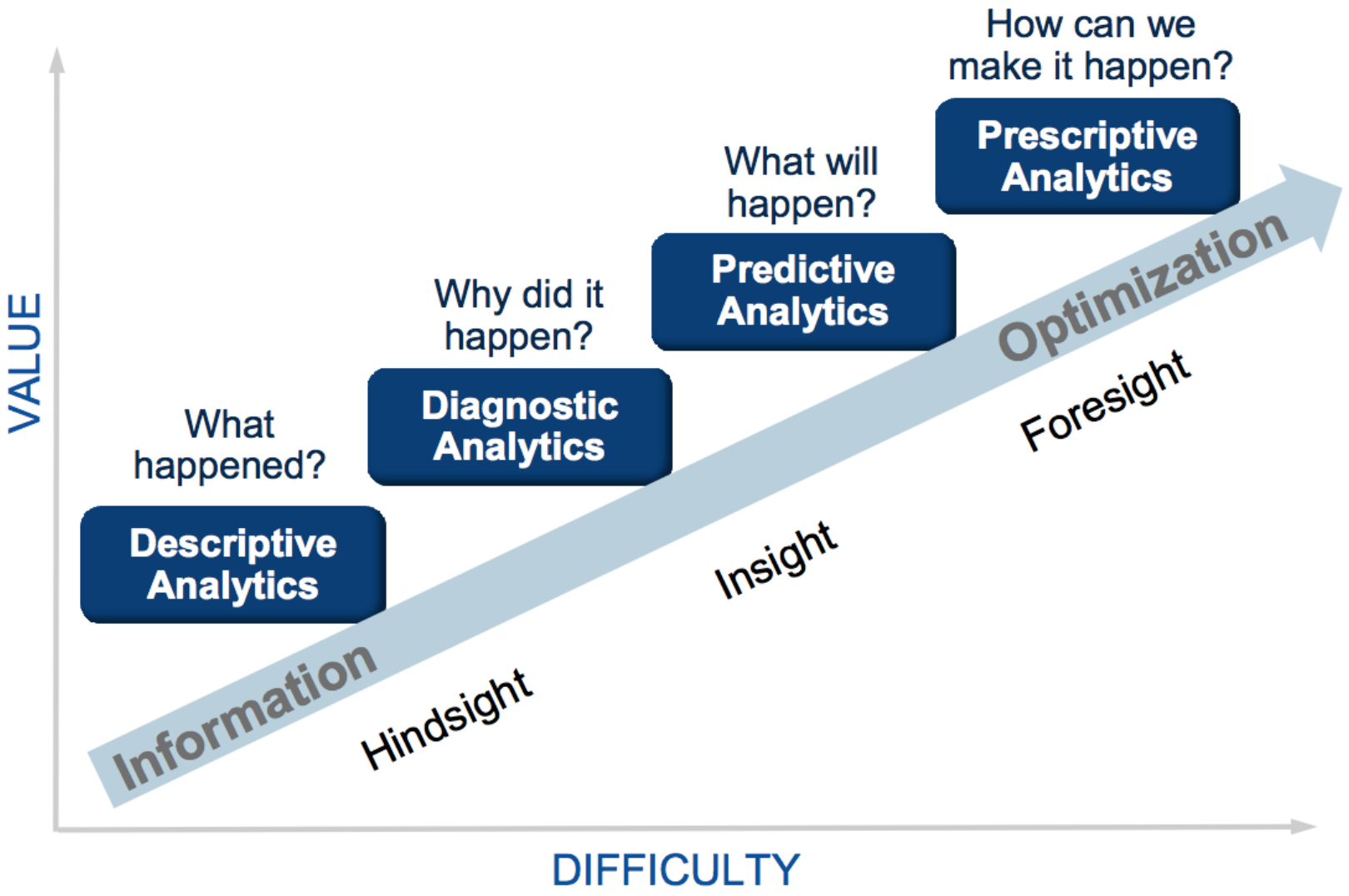
- **Social media** — Likes, trends, retweets, shares, comments
- **Customer profiles and loyalty programs** — Names, addresses, email, preferences
- **Weather and traffic patterns**

Why you need both

Structured data tells you the **"what"**; unstructured data tells you the **"why."** Using both gives you a more holistic view of your customer.

Structured data = data inside of the business team
Unstructed data= data outside of the business team/

What does “data analytics” mean?



Source: Gartner

Reduced costs

- Digital IoT revolution could save $300 billion in healthcare costs
  - More sensors mean more patient monitoring for chronic issues
  - More monitoring means empowered patients, fewer appointments
  - More monitoring means proactive action (sleep patterns, seizures)
  - More monitoring means efficiency when you visit doctors

Vertical	Disease State	Total Savings Opportunity	Commercial Opportunity
Remote Patient Monitoring	Heart Disease, COPD/Asthma, Diabetes,	$200+ billion	~$15 billion
Telehealth	Routine & Psychological Care	$100+ billion	~$12 billion
Behavior Modification	Obesity, smoking cessation, overall lifestyle improvement	Indefinitely large	~$6 billion

Source: Goldman Sachs Global Investment Research

The IoT-enabled future

- Before you wake up in the morning
  - Your bed has sent your sleep-quality data to your physician
- While you're at work
  - Your elderly mother's pill bottle alerts you
  - She has not taken her blood-pressure medicine on time
- On your way home
  - Your refrigerator has informed your grocery-delivery service
  - Soy milk and bread will be arriving at home once you head there

What make a “thing” part of IoT?

- The thing must be **aware**
  - Must be able to collect data about surroundings
  - Healthcare: Blood-pressure, heart-rate, etc.
- The thing must be **autonomous**
  - Collected data must be automatically sent when conditions are met
  - Healthcare: Data must be sent as soon as blood-pressure is elevated
- The thing must be **actionable**
  - Alerts must be raised for intervention (manual or automated) when needed
  - Healthcare: Initiate clinician intervention when blood-sugar level is high

Types of IoT-enabled healthcare “things”

- 80 million healthcare “things” in the next 2 years
- Consumer devices
    - Example: Fitness trackers
- Wearable, external devices
    - Example: Insulin pumps
- Embedded internal devices
    - Example: Pacemakers, miniature body-implanted sensors
- Stationary devices
    - Example: IV pumps

Types of IoT-enabled healthcare “things”

For example, imagine the value to a patient whose irregular heart rate triggers an alert to the cardiologist, who, in turn, can call the patient to seek care immediately. Or, imagine a miniaturized, implanted device or skin patch that monitors a diabetic's blood sugar, movement, skin temperature and more, and informs an insulin pump to adjust the dosage. Such monitoring, particularly for individuals with chronic diseases, could not only improve health status, but also could lower costs, enabling earlier intervention before a condition becomes more serious. Already underway is a clinical trial that equips heart failure patients with sensors to measure key indicators like blood pressure and heart rhythm. By some estimates, there is a remarkable 64 percent drop in hospital readmissions for patients whose blood pressure and oxygen saturation levels were monitored remotely. Less patient-focused but invaluable to health care will be using the IoT to connect medical equipment, such as MRIs and CTs, to remotely monitor and maintain and to replenish supplies, reducing expensive downtime.

Patient tracking

- General Electric's AgileTrac system
  - Hospital-wide industrial-grade Internet
  - Pulls together patient data and equipment data
  - Connects patients to machines and doctors
- Tracking patients with a plastic wristband
  - RFID tags + real-time location sensing (RTLS)
  - All the information input into General Electric's AgileTrac system
- Impact
  - Aventura Hospital and Medical Center, Aventura, FL
  - Cut down 3000 hours in patient-discharge time at a 400-bed hospital

Reducing in-hospital infections

- Reduce transmission of Hospital Acquired Infections (HAIs) to patients
- Fighting hospital infections
  - Proper hand-washing helps to prevent infections
  - CDC data: Hand-washing by providers occurs only 55% of the time
  - Badges count each entry and exit to rooms
  - Sensors track use of soap/sanitizer dispensers
  - Tracking hand-washing can be made into automated process
- Impact
  - Infections created by providers are reduced

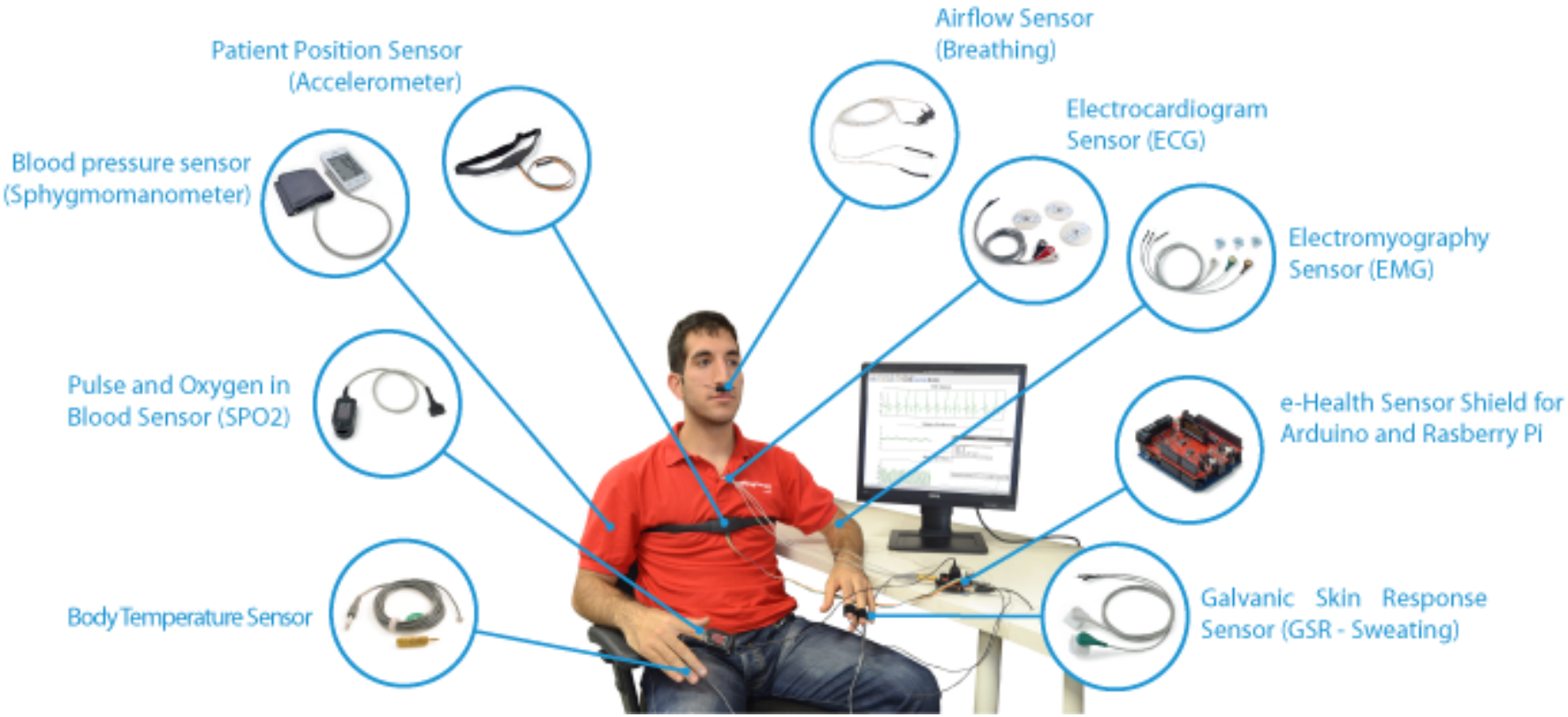
At-home improved care

- Philips' Medication Dispensing Service
- Elderly people forget to take their medication on time
- Elderly people may also end up taking the wrong dosage/medication
- Device alerts a patient to take pills using voice/light reminder
- When a patient pushes a button on the device
  - Right amount of dosage and the right medication
  - Pre-filled cups
- Device also communicates with the phone lines
  - Alerts when person misses a dose
  - Alerts when medication is running out
  - Alerts when power/battery runs out or malfunction occurs

Tracking blood bags

- Blood Center of Wisconsin
- 13.56MHz passive RFID tags on blood bags, shipping containers
- Applied to 75,000 blood bags
- RFID-tag readers at all blood-donation and transfusion sites
- Impact
  - 33% reduction in reconciliation and misplaced products at blood donation
  - 87% reduction in reconciliation and misplaced products at transfusion
  - 63% efficiency improvement at inventory check-in
  - Correct blood product delivered, no misses, for 144 transfusions

At-home and in-room patient sensing



Case-Study Snippets

QUICKSERVICE DRIVE-THRU

A quickservice chain monitors its drive-thru lanes to determine which items to display on its digital menu board. When lines are longer, the menu features items that can be prepared quickly. When lines are shorter, the menu features higher-margin items that take a bit longer to prepare. Those subtle changes in the menu board wouldn't be possible if the company couldn't tap into a steady stream of data in real time to make instantaneous adjustments.

Case-Study Snippets

CHICAGO-BASED LEVY'S RESTAURANTS uses big data to win contracts at stadiums and arenas. Levy's provides high-end, restaurant-quality foodservice at 45 major sports venues. It uses analytics to better understand the correlation between sporting events and food and beverage purchases. It analyzed food trends in Portland, Ore., to create a highly successful 10,000-square-foot restaurant near the Trailblazers' arena.

Case-Study Snippets

PANERA BREAD'S MYPANERA LOYALTY PROGRAM tracks guest purchases and habits through loyalty cards. Guests receive rewards for purchases or when the chain develops a new item similar to previous purchases. The casual-dining chain is leveraging its behavior data with primary marketing research and third-party data to guide its brand strategy, drive new customer acquisition, retain existing customers and assist in real estate planning.

Case-Study Snippets

FIG & OLIVE, a seven-location New York-based restaurant group, has used guest-management software to track more than 500,000 guests and $17.5 million in checks. The restaurants have been able to customize the dining experience for individual guests and deliver results with targeted email communications. Its recent "we miss you campaign" offered complimentary crostini to guests who hadn't dined there in 30 days. The result: Almost 300 visits and more than $36,000 in sales, translating into a return of more than seven times the cost of the program. Matthew Joseph, who leads technology and information systems for the company, says linking POS data with online reservations, plus monitoring social media mentions on Facebook, Twitter or TripAdvisor, helped Fig & Olive create its brand identity and build loyalty.

Case Study: Hitting the Jackpot (1)

Harrah's casino
26 casinos, 13 states
First casino to be listed in the NYSE
In 2003, was a $4.5B company with 44,000 employees, 14400 hotel rooms, 200 food outlets, 42000 slot machines, 1200 table games

Philosophy of customer service and satisfaction originated with the founder, Bill Harrah, and also CEO, Phil Satre

1988, Phil Satre started sending feedback forms and congratulatory forms to slot-machine jackpot winners
Noticed that some customers visited more than one Harrah's property
These multi-site visitors were a fast-growing segment

Case Study: Hitting the Jackpot (2)

Single national Player Card program across properties
Amount of time a person player, along with wins/losses recorded when Player Card was inserted into machine
More playing time meant more points
Points could be traded for complements (comps), e.g., hotel rooms, free meals, show tickets, air tickets

Required overhauling of IT infrastructure
Required card readers to be installed at properties
Decentralized, site-specific systems had to be changed

Focus on improving loyalty at existing sites instead of opening up new properties
Improved sales and marketing
1997, Total Rewards system for tracking 15M+ nationwide guests, rewarding them for repeat business
2000, $65M investment, 3 patents for real-time data technology, competitive advantage

The examples in a casino.

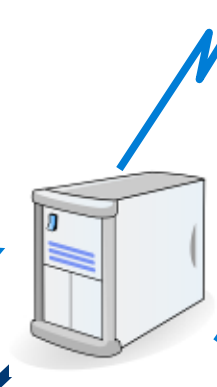
Case Study: Hitting the Jackpot (3)

Case Study: Hitting the Jackpot (4)

2 Sarah has been at the slot machine all day, removes her TR card from the machine.

3 Sarah and John head over to the restaurant at the hotel. They have enough TR points for 2 free buffet meals.

1 John has been playing blackjack all day, now leaves the table. Pit manager records this.



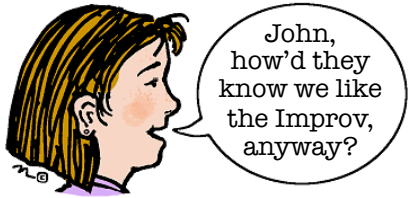
4 Sarah and John are happy they brought their mail coupon for a free night's stay.

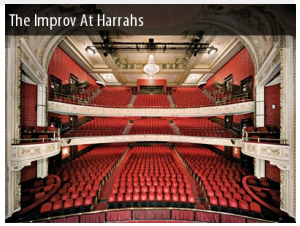
5 Waiter hands them free tickets for an Improv show that night at the casino.

Patron database

Total Rewards (TR) Points accrual and redemption

Promotional offers for related experiences





Like in an airline.

Case Study: Dynamic Ticket Pricing (DTP)

- 2009: the San Francisco Giants introduced dynamic ticket pricing (DTP)
- Ticket prices change daily based on market conditions
- Essentially, demand-based pricing vs. static pricing
- This already happens in the airline industry
- But, this was a first for sports
- 2010: Giants reported a 7% increase in revenue through this strategy
- By March 2012, 17 MLB teams and many NBA/NHL teams implemented this

Case Study: Dynamic Ticket Pricing (DTP)

- Static ticket-pricing model is the classical way of pricing seats
- Based purely on seat location
- Ticket prices are fixed in advance of the season
- Primary market—sports team sells the tickets
- Secondary market—ticket brokers sell the tickets They buy a bunch of tickerts in their inventory.
- Analysis revealed 13 independent variables that influence ticket price
- Season-ticket price, secondary market price, seat location, team performance, individual players' performance, time/day of game, is the game nationally televised, number of All-Star players on the opposing team's roster

Case Study: Dynamic Ticket Pricing

- An additional All-Star in the opposing team's roster
  - DTP price increase of $3
- Opposing team had made the playoffs last season:
  - DTP price of $14 over games vs. an opponent who didn't make playoffs
- Probably appearance by the team's top pitcher (Tim Lincecum)
  - DTP price increase of $7.55
- Statistical performance of Lincecum and Pablo Sandoval affected prices
- Time-related variables had an impact on pricing, too
  - The 7pm game-time starts had a $24 increase over a 1pm start
  - Largest price increases between 30-20 days before schedule game
  - Weekend games priced approximately $8 higher than weekday games
  - Nationally televised games had DTP price of $10

Case Study: Dynamic Ticket Pricing

- An additional All-Star in the opposing team's roster
  - DTP price increase of $3

Time to buy/ Team Playing Performance / Place to buy all of these could change pricing.

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Case Study: Catapult Sports + GPS

They are looking for high intensity motions that will not easily recovered -- injury.

- 2013: Catapult has 300 sports organizations who use their GPS sensors
- Soccer, rugby, hockey, Australian rules football, competitive rowing
- Catapult's OptimEye is a monitoring device on the back of player's jersey
- Catapult's SmartBall is an integrated ball-tracking system
- Wirelessly transmits performance parameters from players on the field
- GPS normally measures only speed and distance
- Catapult has multiple algorithms and analysis of sensor data
- Catapult's **Inertial Movement Analysis (IMA)** is enhanced
- Measures sudden changes in direction, vertical leaps, sudden stops
- Quantifies accelerations, decelerations, changes in direction, jumps
- Gauges workout's intensity and the load on the athlete's body

Case Study: Catapult Sports + GPS

Looking for injury / posssion. How the player will perform differently when they have the ball. Single Athelete load, and high intensity without recovery,

- Catapult's **Repeat High Intensity Efforts (RHIE)** is yet another process
- Combination of inertial sensors and signals
- Identifies signatures of high-intensity athletic effort
- Identifies athletes' high-intensity efforts that don't have adequate recovery
- Highlights fatigue-causing events
- Helps to design practices and workout more optimally
- **Smart Ball** helps with the "story behind each possession"
- Measures time of ball possession, velocity at possession, velocity at disposal
- Records pass chains between team-mates
- Analyzes player movements when they possess (or don't) the ball
- **Tackle Detection** algorithms detect when a tackle has occurred

single athelete and combination of atheletes.

Case Study: English Premier League club

Measure high intensity efforts, dive, goal keeper dives, gives the algoithm, Catapult G5.

Case Study: Catapult Sports + GPS

- 2013: Eight NBA teams used Catapult
- Focus on injury prevention and rehab
- Preventing basketball players from overloading their bodies
- Preventing re-injury during the rehab stage
- Determining thresholds to see when a player is peaking physically
- Determining thresholds to see when a player risks injury, or can return to play

This is not new technology — a number of other sports use it, including some NFL teams. The Knicks used it last season on Jason Kidd.

> ***"Before Kidd returned from injury, he wore the device during workouts to track his acceleration, agility and force. As Forbes' Alex Konrad reported, with a benchmark reading set in the preseason, the team got the numbers it needed to clear him to play. It allows for specific measurements to be met, rather than a player approximating his readiness. How many times have you heard an athlete say he's about 85 percent? What exactly does that mean?"***

Overall: Sports Analytics through IoT is huge

Examples of wearable technology companies for impact monitoring

Company	Sampling of products	Product type	Product functionality	Headquarters
2ND Skull	Cap, Band	Garment	Polyurethane-based composite dissipates impact	Pittsburgh, PA
Athlete Intelligence	Vector Mouthguard, Shockbox® sensor	Mouth guard	Tracks linear and rotational accelerations of head impacts	Kirkland, WA
BrainScope	Ahead 300	Hand-held point of care device	Disposable electrode sensors to detect head injuries	Bethesda, MD
Force Impact Technologies	Fitguard™	Mouth guard	Embedded sensors relate collision intensity via color coded LED's on the front of the mouth guard	Los Angeles, CA Tempe, AZ
Hiji	Hiji Band	Head band	Impact forces, intensity	Phoenix, AZ
Jolt	Jolt Sensor	Sensor	Impact forces, Concussion monitoring. Sensor clipped to garment	Boston, MA
Mamori	Mamori	Mouth guard	Inertial sensors measure impact forces on the head	Dublin, Ireland
Noggin Pro	Noggin, Noggin Pro	Skull caps	Gel capsules in skull cap dissipate forces from skull	Toronto, ON
Performance Sports Group	Q-Collar	Neck collar	Concussion prevention by applying pressure on the jugular vein	Cincinnati, OH
X2 Biosystems	X-Patch Pro X2 Mouthguard	Flexible sensor	Tri-axial accelerometers to measure impact	Seattle, WA

Overall: Sports Analytics through IoT is huge

Summary of methods utilized or emerging to quantify athlete training load to monitor recovery and performance

Method	Used today in sports	Wearables utilized	Metrics	Advantages/disadvantages
Questionnaire	Yes	No	Verbal or written form	*Advantage*: Easy to conduct *Disadvantage*: Highly variable; often inaccurate
Session-rate of perceived exertion	Yes	No	Scale from 1 to 9 detailing intensity of workout. Scale used in conjunction with workout duration to determine load	*Advantage*: Easy to assess *Disadvantage*: Highly variable; often inaccurate
Blood lactate	Yes (emerging)	No	Concentration	*Advantage*: Used to predict anaerobic threshold (kicks in when exercise is increased and the aerobic system can no longer keep up with the body's energy system *Disadvantage*: Cost, inefficient, time-varying process
Tri-axial accelerometers and GPS	Yes	Yes: Catapult, Zebra	Acceleration, location, and velocity used to compute PlayerLoad (arbitrary unit) to derive ACWR	*Advantage*: Easy to utilize *Disadvantage*: Variability in sensor technology could lead to inaccuracy. Need to develop algorithms to filter noise (e.g. player moving on the sideline compared to on-field performance)
Heart rate	No	Yes: Apple Watch, Fitbit, Polar	Time in HR zones, HRV	*Advantage*: Easy to collect large data sets for robust analysis *Disadvantage*: Variability in sensor technology could lead to inaccuracy. Sensor location attributed to deviations.
Muscle oxygen saturation	No	Yes: Humon Hex	SmO_2 levels stratified into workout zones	*Advantage*: Easy to collect large data sets *Disadvantage*: Need for validation of models
Biochemical concentration[5–8]	No	No devices used to monitor training load and recovery directly. Indirect measures include monitoring hydration levels and sweat rate	Concentration	*Advantage*: Insight into the biochemistry of the athlete to predict hypohydration, hyponatremia, and fatigue. *Disadvantage*: Technology still developing. Need to develop predictive analytics based on the biochemical profile of the athlete

Overall: Sports Analytics through IoT is huge

Examples of wearable technology companies with products applicable towards monitoring heart rate and muscle oxygen saturation

Company	Sampling of products	Product type	Product functionality	Headquarters
1st Round Athletics	EnergyDNA™	Body suit	Converts heat to IR which expands blood vessels for greater blood flow	Los Angeles, CA
Athos	Athos Wearables	Vest and pant	Muscle activity and heart signals via EMG	San Francisco, CA
Hexo Skin	Astroskin, Smart Kit	Sleeve	Cardiac frequency, respiratory rate and volume, sleep, acceleration	Montreal, Canada San Francisco, CA
Huawei	Honor Band A1	Watch	Cardio-respiratory fitness	Shenzen, China
Humon	Hex	Device unit	Non-invasive measurement of O_2 content in muscles	Boston, MA
Komodo Technologies Inc.	AIO Smart Sleeve	Sleeve	ECG, heart rate, sleep analysis	Winnipeg, Canada
Kymira	Kymira Sports	T-Shirt	Smart garments for cardiac monitoring to prevent heart attacks in athletes	Reading, United Kingdom
LifeBeam	LifeBeam baseball cap	SmartHat	Embedded sensors measure heart rate and calories	New York, NY
MC10	BioStamp RC™, BioStamp nPoint®, Kintinuum	Epidermal sensor	BioStamp RC™: activity, cardiac activity, EMG, and posture BioStamp nPoint®: activity, posture EMG, and sleep metric, vital signs Kintinuum: quantify treatment efficacy	Boston, MA
Myovolt	Myovolt	Sleeve	EMG to increase circulation, boost muscle power	Hong Kong, China
Rotex Technologies	roMage, roSport, roCare, roFashion	Electronic tattoo	roMage: brain and muscle control, gesture recognition	Austin, TX

Overall: Sports Analytics through IoT is huge

Examples of wearable technology companies for monitoring the biomechanical forces on the athlete

Company	Sampling of products	Product type	Product functionality	Headquarters
CricFlex	CricFlex	Sleeve	Measures arm angle and force during bowling	Islamabad, Pakistan
Heddoko	Heddoko	Smart Garment	Biomechanics of movement, deviation from benchmarks and movement standards, injury risk	Montreal, Canada
Motus Global	mThrow™, motusPro™	Sleeve	Accelerometer to measure joint angles, velocity, stress, strain	Massapequa, New York Ft. Lauderdale, FL
Protonics Technologies	Protonics T2	Device	Offsets left-right biomechanical imbalance to reduce muscle pain. Attached to left leg	Lincoln, NE

Overall: Sports Analytics through IoT is huge

Examples of wearable technology companies for monitoring sleep

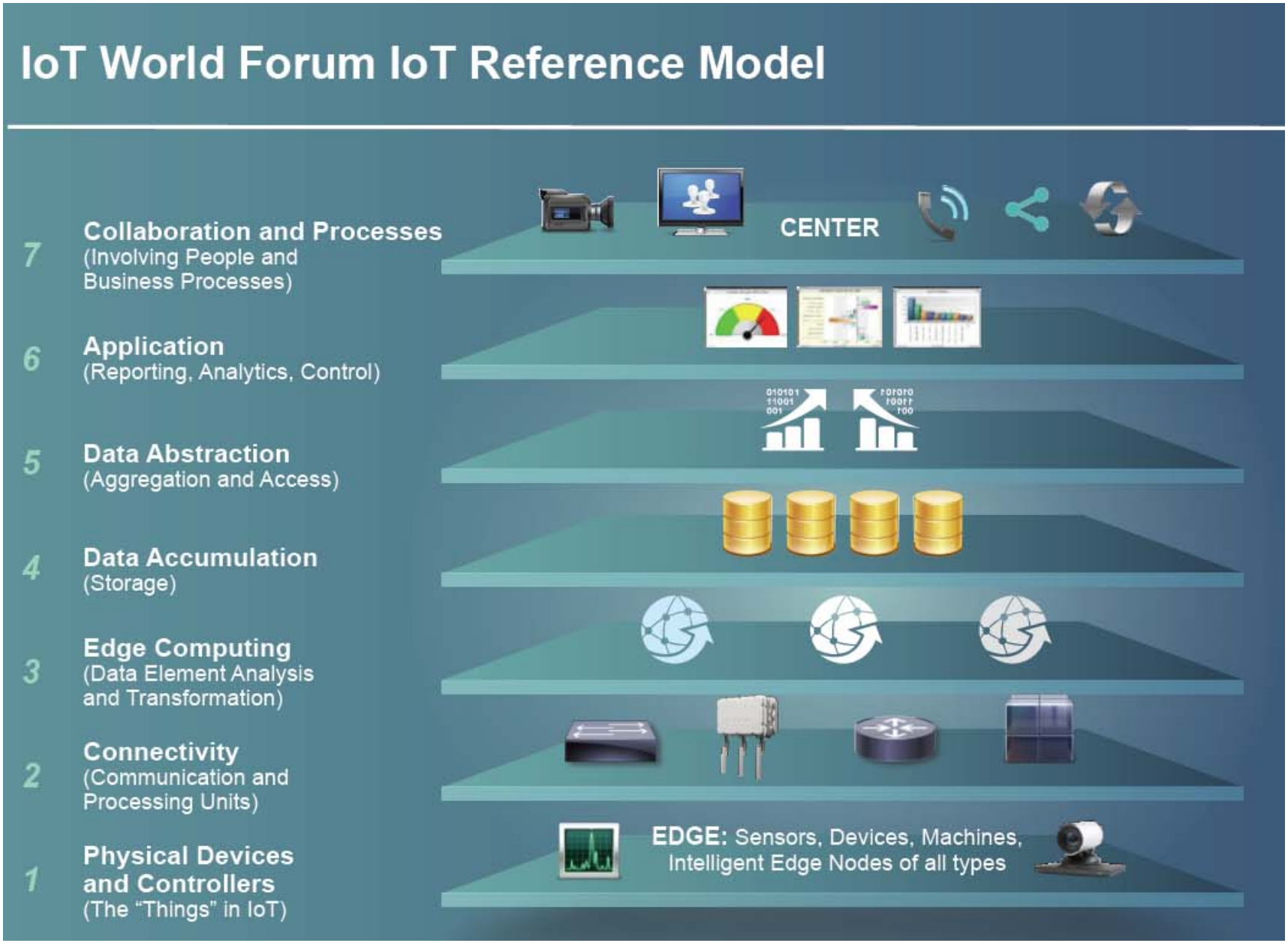
Company	Sampling of products	Product type	Product functionality	Headquarters
Emfit	Emfit QS	Device unit	Tracks sleep by monitoring movement and heart rate	Vaajakoski, Finland
Kokoon	Kokoon	EEG Headphones	Movement and EEG sensors determine relaxation and sleep quality	Limerick, Ireland
Moov	Moov	Wrist-based device	Heart rate, sleep quality, and activity tracker	San Francisco, CA
WHOOP	WHOOP Band	Wrist-based device	Heart rate, body temperature, movement, and sleep	Boston, MA

Overall: Sports Analytics through IoT is huge

Examples of wearable technology companies with products applicable towards assessing the position and motion of the athlete

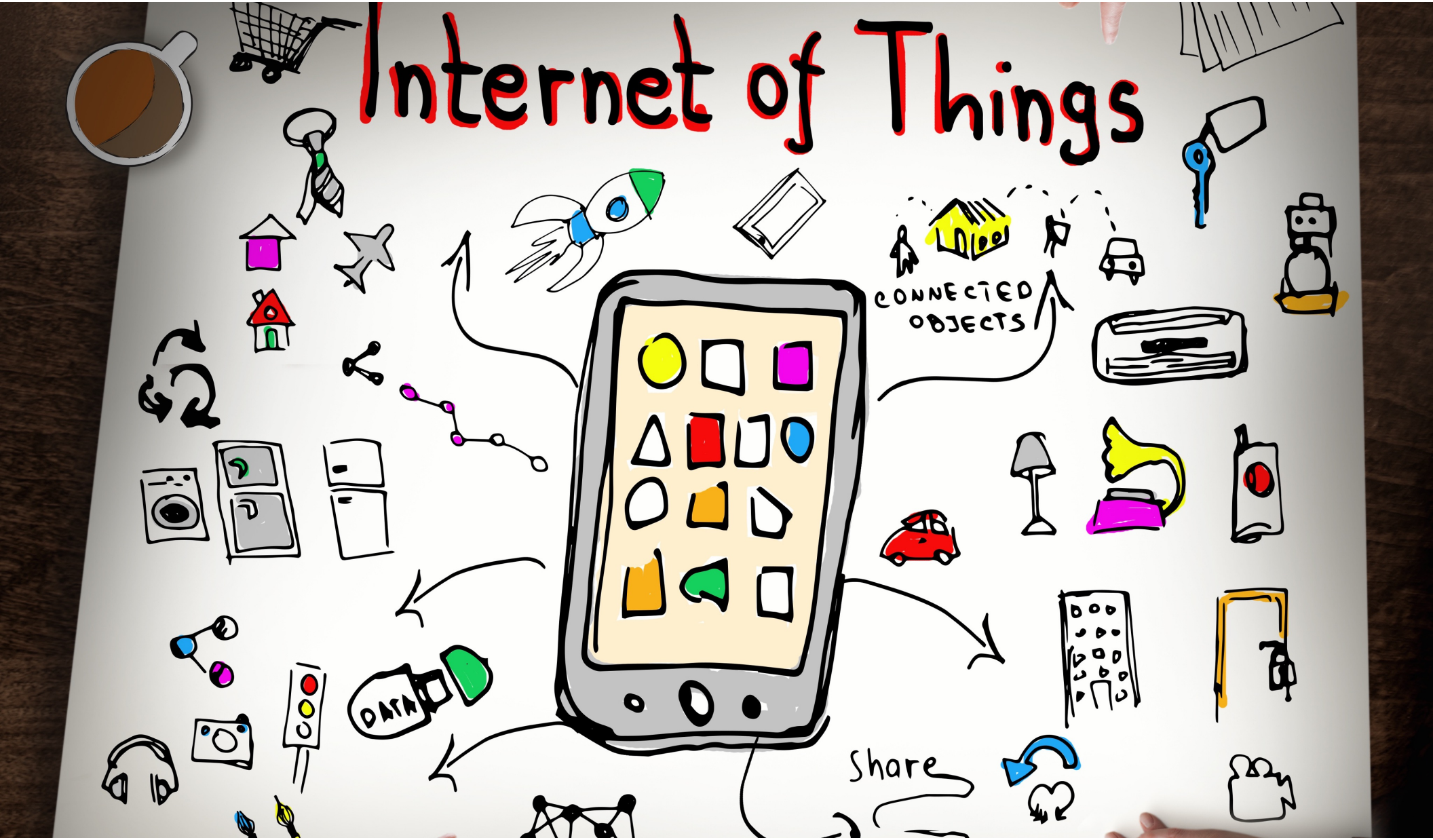
Company	Sampling of products	Product type	Product functionality	Headquarters
Adidas	miCoach Fit Smart, miCoach Smart Run	Watch	Heart rate, GPS, distance	Herzogenaurach, Germany
Apple	Apple Watch	Watch	Heart rate, distance, email, ECG, text messages, phone	Cupertino, CA
BioSensive Technologies Inc.	Joule	Earrings	Heart rate, calories burned, steps taken, overall activity level	Ontario, Canada
Catapult	OptimEye S5, Vector	Device unit	Movement, Turn rates, orientation, heart rate. Device placed below the neck (tucked in shoulder pads)	Melbourne, Australia
Fitbit	Flex, One, Alta	Watch	Steps walked, distance, heart rate, sleep quality, pedometer, calories burned	San Francisco, CA
Garmin	Vivoactive, Vivosmart, Vivofit	Watch	Pedometer, sleep quality, heart rate, distance	Schaffhausen, Switzerland
Jabra	Sports Pulse Wireless Headphone	Headphone	Accelerometer and heart rate monitoring	Ballerup, Denmark
Jawbone	Up	Band	Pedometer, distance, heart rate, sleep quality, calories	San Francisco, CA
Karacus	Polaris, Zeta, Proxima	Watch	Movement, phone, email	Chapel Hill, NC
Kitman Labs	Capture	Sensor mounted	Biometric data via machine learning,	Dublin, Ireland

Recap


IoT World Forum IoT Reference Model
7
Collaboration and Processes
(Involving People and Business Processes)
6
Application
(Reporting, Analytics, Control)
5
Data Abstraction
(Aggregation and Access)
4
Data Accumulation
(Storage)
3
Edge Computing
(Data Element Analysis and Transformation)
2
Connectivity
(Communication and Processing Units)
1
Physical Devices and Controllers
(The "Things" in IoT)
CENTER
EDGE: Sensors, Devices, Machines, Intelligent Edge Nodes of all types

One of the first element leads into SportVue.

Sports Analytics Transforming NBA Teams



Sports Analytics

18-738 Sports Technology

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